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# Measurement Techniques

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# Measurement Techniques

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# RAISING THE LEVEL OF MEASUREMENT TECHNIQUES IN THE NATIONAL ECONOMY

Translated from Izmeritel'naya Tekhnika, No. 6, pp. 1-4, June, 1960

Since the June Plenum of Central Committee of the Communist Party of the Soviet Union (1959) considerable work has been carried out in our country with respect to applying new measurement techniques, raising the quality of the measuring equipment and means of automation and improving their utilization. The scientific research institutes, design offices and plants have carried out a considerable amount of work in making new instruments and introducing them into our national economy.

However, the check carried out by the Committee of Standards, Measures and Measuring Instruments has shown that obsolete instruments are still being produced. In this connection the Committee in the second half of 1959 alone forbade the production of over 90 types of obsolete instruments which did not satisfy, in their technical characteristics and reliability of operation, the latest requirements of modern techniques.

The 1960 state inspection plan for reference measures and measuring instruments provides for the testing of more than two and a half times as many instruments as in 1959. The types of instruments being prepared for production have also considerably changed, emphasis being laid on automatic control instruments.

Among the instruments prepared for state testing and production in 1960 one should mention a large group of automatic high-speed potentiometers and bridges of high precision up to class 0.2, of voltmeters with digital displays, remote measuring devices for ac voltage and current measurements, a series of secondary electronic control instruments, automatic dosimeters, for various materials, corrosive liquids flow gauges, automatic electronic pH-meters, instruments for automatic measurement and control of density and viscosity of liquids, a series of automatic gas analyzers, and a large quantity of radio-measuring and other instruments.

In connection with the preparation of plans for the production of instruments in 1961, the Committee of Standards, Measures and Measuring Instruments has proposed to discontinue the production and modernize more than 200 additional instruments and bring into use over 170 new and more perfected instruments.

The agencies of the Committee have also intensified the control over the quality of production of the instrument-making plants. Regulation 2-59 has come into force on April 1, 1960 providing for state testing of measures and measuring instruments both new and those already in production.

The new regulations have been drawn up to meet the tasks raised by the Twenty-First Congress of the CPSU and the June Plenum of the Central Committee and are designed for speeding up the technical development and the speedy assimilation of new measurement techniques.

In supervising the quality of production of measures and measuring instruments the State inspection laboratories have checked last year over 38 million measures and measuring instruments.

In enforcing state standards and technical specifications the agencies of the committee have found many serious defects in the quality of the manufactured measures and instruments. Thus, the quality of production of several plants in the Byelorussian, Gor'kii, Tartar, and Armenian Councils of National Economy is low.

The time has come when a radical change can be made in improving the quality of production in the instrument-making industry. It is necessary to eliminate from production every thing which is obsolete or imperfect, and without delay master the production of new designs. The State Inspection Laboratories for measurement equipment must change their manner of working, directing their main effort toward the most important of their tasks, in connection with instrument making and assimilation of new techniques, concentrating on this task their best personnel.

The heads of the State Inspection Laboratories must supervise personally this work, and organize control of instrument making in such a manner as to stop production of instruments which do not satisfy the state standards and technical requirements.

In carrying out their inspection work they should actively participate in eliminating the defects found in testing instead of limiting themselves to a mere enumeration of faults in design or quality of the instruments and making of suggestions for eliminating them. In addition to the Technical Control Division personnel, factory and workshop inspectors and experts of the customer plants should be encouraged to take part in the inspection work.

It should always be remembered that one of the main criterions in evaluating the work of the State Inspection Laboratories is the results they achieve in improving the quality of production, and assimilating new techniques in the production and utilization of instruments.

One of the important reasons which prevent the improvement of the quality of measuring instruments is in many cases the unsatisfactory study of the operational properties of instruments by the plants. In addition to using field testing equipment at the manufacturing plants (simulating equipment), it is also necessary to use on a wider scale and in a more organized manner the services of plants and organizations which use the instruments and have the required laboratories and specialists for a systematic observation of the operation of the instruments and means of reporting the defects thus discovered to the manufacturing plants. The State Inspection Laboratories should render greater assistance to the plants than they are doing at present both with respect to organizing this work and informing the plants about their own conclusions based on the study of the behavior of instruments during testing and inspections carried out in various branches of our national economy.

Serious defects were discovered in compiling technical instructions for measuring instruments, when in many cases operating standards and specifications were disregarded and the existing technical achievement were not taken into account. Cases when in the manufacture of instruments technical requirements were not observed are not infrequent. It is necessary to take decisive measures for improving the technical instructions and for conducting systematic work with the object of making the specifications and requirement more precise, thus contributing greatly toward a further improvement in the quality of the instruments.

One of the basic and decisive measures for the improvement of the technical level in instrument-making is standardization and normalization. In the past and current years the main attention was paid to the standardization of measuring instruments, which provided industry with better means of measurement, including instruments connected with production automation. Thus, a new standard for instruments measuring the size of details of plane-grinding machines has been approved and will in future serve as a basis for the development of new designs and unification of existing control instruments. For the first time a standard has been adopted for measuring internal dimensions up to 500 mm with smaller tolerances than those adopted abroad.

Improved standards have been adopted for manometers, vacuum manometers and vacuum gauges for general use which will double the accuracy of measurements as compared with the existing accuracy.

A number of standards for modern electrical measuring instruments have been adopted, including a general standard for technical requirements of electrical measuring instruments and standards for dc potentiometers with an accuracy of measurements three times higher than the existing one. With the view of increasing the quality of instruments and raising the precision of measurements standards were improved for hole gauges, wobble gauges, deviation gauges, gear-tooth gauges, pitch gauges and other instruments used in engineering for linear and gear measurements.

Standards for nomenclatures in automatic control systems and for input and output parameters in pneumatic automatic control systems have been approved. Standards are being prepared for electronic amplifiers in automatic instruments, for synchronous motors and means of automation, automatic and semiautomatic gas analyzers and several other standards.

The task of the near future, and in the first instance for basic organizations, is the speedy elimination of lagging in standardization of such important spheres of technology as control and automation, combined systems of control and regulation, dosimetric and radiometric measurements and computers.

It is necessary to extend and speed up the work of standardizing and normalizing units and components in instruments, especially of instruments in general use, manufactured in large quantities. Without this measure it

will be impossible to organize the specialized production of components for instruments and automatic equipment.

In this respect the most important measure is the assimilation by the industry of the prepared standards and specifications.

The metrological institutes of the Committee play an important part in raising the level of measurement techniques.

By the beginning of 1959 our state standards and basic measures in the majority of the principal spheres of measurements were at the level of the large metrological laboratories of the world and in certain spheres exceeded them both in the range covered and in the precision of their characteristics.

However, the rapid development of our national economy planned by the Twenty-First Congress of the CPSU, especially in the new spheres of technology, requires the raising of the accuracy already achieved and in the first place a further improvement in the technical level of reference units and the development of work for the establishment of better reference standards, means of measurement and methods of transferring precise values of reference standards to working standards and instruments.

The metrological institutes of the Committee have achieved certain successes in the solution of these questions, having established new standards for magnetic units based on nuclear resonance, having transferred reference length measurements to comparison with light wavelengths, having accurately determined the values of superhigh pressures over an extended range, having established reference equipment in the sphere of ionizing radiations, having made more precise and extended the range of the International Temperature Scale and created reference means for various types of measurements.

During the period in question the Committee's institutes have developed a number of reference and standard instruments and equipments.

Several new designs of the metrological institutes have been accepted for mass production by plants of the Krasnodar, Gor'kii, and Tallinn Councils of National Economy, and in 1960 their first batches should appear on the market.

The Committee has also prepared new proposals for the adoption by the industry of design completed by the institutes.

Serious attention should be paid to developing methods and equipment for the automatic checking of measures and instruments. This is especially important for instrument-making plants where a large checking equipment stock is maintained. This is of great importance also for inspection agencies which supervise the condition and accuracy of measurement equipments used in the industry.

The Committee's metrological institutes and certain instrument-making plants are pursuing these tasks. Thus at the present time the metrological institutes are developing a contactless method of checking gauge blocks, an automatic method of measuring interference fringes when checking end gauges, an automatic method of checking linear measures of length, improved reference voltmeters and other electrical measuring instruments with digital displays and 0.02 grade accuracy in order to speed up the checking of grade 0.1, 0.2 and other instruments.

A few instrument-making plants have successfully solved the problem of automatic testing of electricity meters.

The above work is only a beginning and it should be extended to include a wide circle of people who work in factory test laboratories industrial institutes and instrument-making design offices.

The assimilation of the new techniques should be carried out according to a plan which would take into account all the peculiarities of production. Special attention should be paid to problems of economic efficiency and profitability of placing on the market any particular type of instrument.

Planned assimilation of modern means of measurement and elimination of obsolete instruments is being carried out by many Councils of National Economy of the Ukrainian SSR and in certain plants of other Union Republics, which have drawn up plans for the replacement of the obsolete measuring equipment in the near future. An important role in this task is assigned to the State Inspection Laboratories which in conjunction with

plants and Councils of National Economy should develop plans for the introduction of new measuring techniques. It is necessary to extend without delay the successful experience already gained in assimilating new techniques to all the branches of national economy.

Great importance in introducing new measuring equipment and supervising its correct utilization is assigned to agencies which are exercising in the plants a constant supervision of measures and instruments, the factory test laboratories, control and measuring instrument shops, automation shops and other agencies.

The forthcoming Plenum of the CPSU Central Committee in July, 1960, will check on the fulfilment of the decisions taken by the Twenty-First CPSU Congress regarding the development of industry, transport, and the introduction into industry of the latest achievements of science and technology, and the decisions of the Plenum will help the metrological and instrument making workers to tackle even better the problems which face them in the sphere of assimilating new measuring equipment and speeding up technical progress in all the branches of national economy.

## ASSIMILATING NEW MEASUREMENT TECHNIQUES IN PRODUCTION

A. I. Ponomarev

Translated from Izmeritel'naya Tekhnika, No. 6, pp. 4-5, June, 1960

In fulfilling the tasks assigned to them by the Plenum of the Central Committee of the Communist Party of the Soviet Union (1959) the Administration of the Plenipotentiary Committee attached to the Ukr.SSR Council of Ministers and the state inspection laboratories for measuring equipment have intensified their cooperation with the Councils of National Economy, their industrial agencies and plants, and especially with factory test laboratories, and organized joint work in a planned replacement of the obsolete by modern measuring equipment.

On the initiative of the Administration, entrusted with this work in October 1959, plans were drawn up for supplying the required measuring equipment to the Councils of National Economy, ministries, administrations and regional Soviet executive committees, which are expected to introduce new and improved methods and means of measurement and automatic control, and the measures which should be included in the plans for assimilating the new equipment by the subordinate organizations were outlined.

We accumulated considerable experience in assisting various agencies in introducing new equipment.

In the first place factories drew up yearly plans for assimilating new measuring equipment and certain plants compiled advanced plans extending to 2-3 years. Some of the plants included the measuring equipment plans in their general plans for assimilating new equipment. Each factory was obliged to present appropriate requests to the Councils of National Economy and the State Planning Committee of the Ukr.SSR for the required measuring equipment.

The State Inspection Laboratory personnel helped the factories and organizations to work out their technical plans for assimilating and selecting the required measuring equipment. The State Inspection Laboratories used in this work the data supplied in the bulletins on measures and measuring instruments which had passed their state inspection, in the information material of the VNIIM (All-Union Scientific Research Institute of Metrology), in the journal Izmeritel'naya Tekhnika ("Measurement Techniques"), in the brochures of the All-Union Exhibition of the Achievements of our National Economy and other technical literature; the catalogs of the Glavpriborsbyt (main instrument selling agency) of the Ukr.SSR State Planning Committee were also often used. These sources of information on instruments produced by our industry are, however, insufficient and the required measures should be immediately taken to supply the laboratories with complete information material on the measures and measuring instruments made in the USSR.

For a further intensification of the work in discovering obsolete and replacing it with new measuring equipment, the Administration has envisaged concrete measures which are being implemented by our laboratories and in particular has carried out investigations according to a special program.

In the republic, 95 investigations were carried out in 1959.

In order to eliminate the defects thus found, the factories and Councils of National Economy have drawn up organizational measures, organized conferences for the exchange of experiences which were attended by the chief engineers and heads of the Central Test Laboratories and other personnel of the plants.

Such a conference was, for instance, held in Zaporozh'e in 1959 [see "Measurement Techniques", 11, 66 (1959)].*

The Kiev Sovnarkhoz (Council of National Economy) in conjunction with the State Inspection Laboratory personnel held a conference on the question of replacing the obsolete by modern measuring equipment. The conference was attended by the chief engineers of the factories concerned and by the heads and chief engineers of the Sovnarkhoz departments.

At the 1959 conference dealing with the quality of the goods produced by the L'vov Sovnarkhoz, the question of increasing the supply of the latest instruments was discussed in connection with establishing automatic lines in certain plants, mechanizing production processes, and monitoring certain technological processes.

In October, 1959, the Administration organized in conjunction with scientific and technical departments of the instrument-making industry and the Khar'kov State Institute of Measures and Measuring Instruments a conference in Kiev on modern achievements in the sphere of automation and mechanization of control operations in linear and angle measurements and the introduction of modern means and methods of measurement in engineering and instrument-making [see Measurement Techniques, No. 12, (1959), page 61].

Measures required for the introduction of new measuring equipment are usually discussed with representatives of factories and workers in departmental inspection at all the conferences organized by the GKL (State Inspection Laboratories) which deal with questions of control, and the enforcement of state standards and specifications.

All the GKLs distribute among the various establishments of the republic information material of the VNIIK (All-Union Scientific Research Institute of the Committee of Standards, Measures and Measuring Instruments) in order to make them acquainted with new instruments and bring to their notice drawings, circuits and descriptions of testing equipments and devices.

The above measures assisted the further assimilation of new measuring techniques and means of automatic control of production. The results thus achieved can be illustrated by a number of examples. In the forge of one of the plants (Zaporozh'e region), on the suggestion of the GKL, automatic temperature control was introduced in 7 annealing ovens. Before the investigation carried out by the GKL obsolete pyrometric milliammeters were used for controlling the temperature of ovens and the available automatic potentiometers were neglected.

Following the recommendations made by the Dnepropetrovsk GKL as the result of its investigations, the local electromechanical plant installed and is now using a balancing machine of the MPB-14 type for routine testing of electric motors; a high voltage cage has been constructed for testing the insulation of motors; in the thermal department, automatic temperature control of the electric oven has been introduced; several devices for checking universal measuring instruments have been made to the GKL design. At the cast-iron rolling mill technical specifications for an automatic programmed temperature control of drying and flame ovens were developed with the view of introducing the improvements in the first half of 1960; cupolas have been supplied with the appropriate equipment in view of their transfer to natural gas supplies. In the aluminum plant the wet mills have been transferred to automatic and dispatcher operation; in the calcination department 4 oven chamber feeders have been made automatic, and the loading and unloading of these feeders as well as the centrifuge department have also been automatized. The economic advantage of automation in this plant has not yet been calculated, since all the required work has not yet been completed, but certain preliminary data is already available. Thus, the output of alumina has increased by 28%, and 18 men were made available for other work, a large economy

*See English translation.

in caustic, steam, water and air has been achieved and the technology of production improved, as well as the conditions of manual labor.

The personnel of the Kiev GKL assisted the "Ukrkabel'" plant in installing electronic temperature regulators required for controlling production temperatures; help was given for making use of the stocked instruments which were lying idle. For instance in the Lepse plant 6 flowmeters and 42 automatic potentiometers which had been stocked for a long time were brought into use. It is interesting to note that previously, in many parts of the plant, the expenditure of gas, steam and water was not checked and obsolete instruments were used for measuring temperature. At the "Krasnyi Ékskavator" plant and the automobile repair plant No. 12, the internal diameters of components were measured by indicating hole gauges, whereas the pneumatic instruments existing at the plants for this purpose were not being used, etc.

Following the recommendations made by the Crimea GKL, the Saki bromine plant constructed a special installation for checking the level of chlorine in its storage tanks; a floating differential manometer for measuring the quantity of chlorine used by the bromine shop was installed; resistance thermometers and a three point electronic bridge were brought into use for automatic registration of the temperature of brine in vats used for the production of magnesium chloride. Thus, the production process became continuously controlled and the workers who previously checked the temperature by means of indicating instruments became available for other work. A method of controlling the amount of gas by means of electrical measuring instruments calibrated in volume units has been introduced, thus providing a continuous control of the flow of gas in the gas generating and hydrogen departments; the mercury thermometers used for controlling the preparation of persalts have been replaced by recording manometric thermometers type MT-610; a vacuum gauge type VS-410 has been installed at the thermal electric power station for controlling vacuum in a capacitor; a portable equipment for checking electrical pointer instruments in situ has been manufactured and put into use; improvements have been introduced into the potentiometric equipment of the factory laboratory. As the result of the improvements thus introduced, the Saki plant has saved considerable sums in 1959.

Similar examples of help in introducing new measuring equipments in plants can be cited for all the laboratories of the Ukrainian SSR.

## THE STUDY OF MEASUREMENT INSTRUMENTS' OPERATIONAL PROPERTIES

M. D. Kalennikov

Translated from Izmeritel'naya Tekhnika, No. 6, pp. 6-7, June, 1960

One of the basic tasks of the state inspection laboratories for measuring equipment consists of systematic supervision of the behavior of measuring instruments in operation and the study of their operational properties and qualities of their design.

The Kiev GKL (State Inspection Laboratory) assigns great importance to this work and pays special attention to it. The instruments are studied according to the instructions issued by the Committee of Standards, Measures and Measuring Instruments and the instructions developed by the Kiev GKL to suit local conditions.

The quarterly laboratory plans always include, in addition to other items, the study of certain instruments with the required time allocated for the purpose.

In studying the quality of the instruments the laboratory sends out many questionnaires to the users of the instruments.

Over 1000 establishments and organizations which use the instruments under study were questioned in 1959. The laboratory questionnaires in the form of special printed sheets included the following questions: the condition of instruments at the time of their reception from the manufacturing plant, completeness of accessories,

quality of packing, damage in transport, operation during guaranteed period, length of service without repairs, defects discovered during their operation due to the design of the manufacturing quality of the instruments, values of errors, conditions of use, other remarks and suggestions. Statements are expected to be accompanied by concrete examples, references to the numbers of instruments and indications of the year of their manufacture. As a rule the establishments provide willingly valuable technical reports on the condition of the instruments.

In order to attract to this work wider circles of people connected with measurements, the GKL insisted that instructions should be issued to inspection laboratories, inspection agencies, and instrument repair shops by their respective heads to organize groups of qualified workers for dealing systematically with the questionnaires and entering observations on their instruments in special logbooks. This work is carried out, for instance, at the "Tochélektropribor" plant, in the thermal control and automation shop of the Kiev GÉS-2 (Hydroelectric Power Station No. 2), in the KIP shop (control and measuring instruments) of the artificial fiber plant, in the instrument repair shop of the "Proménergoavtomatika" combine, etc.

In studying the operational qualities of the instruments state test data is taken into account. For this purpose in all types of measurements logbooks are kept for entering test results and remarks on the quality of the sets.

The study of the instruments includes their comparison with the best similar types produced at home and abroad.

The results of such studies are summarized in technical reports signed by the persons directly responsible for the investigation of the set in question. The report is approved by the head of the laboratory after checking that it is correct and technically sound.

In agreement with the results obtained from these studies letters are sent to the manufacturing plants suggesting various improvements, modernization or scrapping of the instrument as obsolete. Reports on instruments produced outside a given region are also sent to the Committee of Standards, Measures and Measuring Instruments.

The laboratories supervise the implementation of their suggestions through the good offices of the Councils of National Economy, by sending them summaries of their studies with a request to intervene in the plants which are slow in eliminating the defects in the instruments or withdrawing from the market obsolete sets. Some of the material is discussed at technical conferences organized by the chief engineers of plants.

The results obtained from studying the operational properties of instruments are widely used by the GKL in testing the current production of instrument-making factories.

In 1959 the Kiev GKL studied the operational properties of 68 gauges and measuring instruments and made appropriate suggestions. In the overwhelming majority of cases the manufacturing plants implemented the suggestions. Thus the production of gasoline pumps type DDB-40, hygrometers type 2É-2, automatic scales type DS-500-2 and several astatic electrical instruments and other instruments was discontinued. In many instances manufacturing plants have introduced improvements in their products according to the test material supplied to them. This happened, for instance, in the case of automatic scales type DS-800, multirange combined instruments type Ts-51 and Ts-52, portable cable test sets PKP-2, etc.

When the operational properties of instruments are studied, production expenses which the plants suffer as the result of defects in the instruments or their failure before the guaranteed life are usually taken into account. When gasoline pumps type DB-40 of the Kiev "Neftoizmeritel' " were tested it was found that for every 100 pumps a sum of 2500-5000 rubles had to be spent unproductively on premature repairs. On the repairs of 100 gas meters type RS-600 of the "Kievpribor" plant 22,000 rubles had to be spent each year, and 2,400 rubles on repairs of 100 electricity meters type SO-2. The cost of repairs of electrical measuring instruments M-132 and M-130 of the "Vibrator" plant before their guarantee expired amounted in a single establishment during nine months of 1959 to 16,700 rubles.

All these facts show that large sums belonging to the State are being lost due to the low quality of measuring instruments.

The study of the operational properties of instruments is very important.

The personnel of State Inspection Laboratories for measuring equipment must develop and improve this type of work.

# MEASUREMENT TECHNIQUES AND THE MEASUREMENT SERVICE IN THE POLISH PEOPLE'S REPUBLIC

Prof. Dr. Ya. Obal'skii and Engineer V. Voityla, M.Sc.

Translated from Izmeritel'naya Tekhnika, No. 6, pp. 7-8, June, 1960

The organization of the measurement service in Poland is closely connected with the establishment of the socialist regime. It is only under socialist conditions that metrology and measurement techniques become one of the basic elements in the technical progress of people's Poland.

In the Polish People's Republic metrology and measurement techniques are controlled by the Chief Measures Administration. The greater part of the inspection work is carried out by the 7 regional and 63 district administrations, leaving the Chief Measures Administration to deal with special and high precision instruments. In addition the Chief Administration carries out scientific research work in metrology, tests and approves new types of measures and measuring instruments, checks reference apparatus which is used in regional administrations, and supervises the activity of these administrations. The Chief Measures Administration has 24 laboratories, without counting the laboratories of the regional administrations, a design office and mechanical workshops. Of the 960 workers of the measurement service 272 work at the Chief Measures Administration.

One of the most important tasks of the laboratories of the Chief Measures Administration is the speedy and efficient testing of the new types of instruments.

The time measurements laboratory has a time standard and a set of three quartz crystal clocks with a relative error of $10^{-7}$ and a stability of $10^{-8}$ (for one month).

The linear measurements laboratory has a set of four platinum state standards compared with the standards at the International Bureau and those at the D. I. Mendeleev All-Union Scientific Research Institute of Metrology. The universal comparator in the possession of the laboratory provides comparisons between the State and working standards with an error of $10^{-7}$. The laboratory interferometers provide both comparative and absolute measurements of block gauges.

The laboratory for measuring mass has a state platinum-iridium kilogram standard, which is a copy of the international standard reproduced with an error of $10^{-8}$. The lack of appropriate balances, however, prevents its use. Therefore use is made of secondary standards compared with British State standards at the National Physical Laboratory.

The laboratory for measurements of force has an equipment which provides measurements in the range of 1 to 50 ton-wt.

The hardness measuring laboratory as yet measures hardness only to the Rockwell scale.

In the electrical measurements laboratory, units are reproduced by means of sets of resistors and standard cells, (we have no current balances as yet) with an error of $10^{-6}$ for resistances and $5 \cdot 10^{-6}$ for voltages. The laboratory equipment provides measurements up to 3000 amp and 800 v, dc, and 3000 amp and 110 kv at 50 cps.

In 1960 the electrical laboratory will be equipped for measuring at higher frequencies. The high tension department has a three-step pulse generator of 500 kv.

The thermometric laboratory has only secondary standards checked in metrological laboratories of other countries. The laboratory is now working on reproducing reference points of the International temperature scale.

The photometric laboratory possesses only secondary standards of brightness and luminous flux obtained abroad.

The recently organized laboratory of ionizing radiations has two radium standards of 14.8 and 24.4 mg. Work is being conducted for the production of a state standard roentgen unit for measuring radiations of 15-60 and 50 kev.

The cooperation of the measurement service with industry does not mean that this service checks directly all the measuring instruments at the factories. In the majority of cases the inspection is carried out by the establishments' personnel, and the role of the measurements administration consists in supplying industry with the required instruments, specifications and instructions, in carrying out general supervision of their execution and assisting in the training of inspection laboratories' personnel. These principles are now being applied in the engineering industries, where since 1949, following the example of the Soviet Union, a network of laboratories has been established in which the reference equipment is concentrated. The organization of test laboratories has proved its worth and other industries (chemical, metallurgical, ceramic) are beginning to use reference equipment certified by the Chief Measures Administration.

These industries use mainly instruments for measuring electrical quantities, pressure, temperature and the flow of liquids and gases, etc.

One of the main defects of the technical inspection agencies in our industry is the fact that they are badly equipped with reference equipment and lack qualified personnel.

The rapid industrialization of Poland in the last 15 years has produced a great demand for measuring instruments and led to the development of our own instrument-making industry, which now produces practically all the required types of measuring instruments. Special instruments in small quantities are being produced in workshops and laboratories of scientific research institutes and, departments of higher educational establishments (the Electrotechnical Institute, the Central Measuring Equipment Laboratory, the Thermotechnical Institute, and several institutes in the chemical, sugar, metallurgical, textile and other industries). These institutes and departments also develop in cooperation with the Chief Measures Administration new types of instruments intended for general application.

The Polish Academy of Sciences is playing an increasing part in developing new measuring methods and designing new equipment.

One of the main factors in the development of measurement techniques is production automation, which sets particularly strict requirements on the efficiency of measurements. Although automation is only beginning to develop in Poland, its effect on the technique of measurements is already apparent.

Measurement equipment is beginning to play an increasing role in agriculture, medicine, safety precautions, labor protection, etc.

The development of measuring equipment has made it necessary to establish or extend in all the higher educational establishments, metrological departments with special laboratories. Thus, in 1953, the Warsaw Polytechnical Institute established a faculty of mechanics precision which trains design engineers and technicians for measuring instruments. The faculty has organized departments of technical metrology, design of precision instruments and optics, and a department of automation is being established.

The training of technicians is carried out either at the plants or at classes organized by scientific-technical societies. For instance the Chief Measures Administration and the Society of Polish Engineers, Technicians and Mechanics (SIMP) have organized courses for workers in measurement laboratories in the engineering and electrical industries. In several scientific and technical societies special departments have been established, which deal with measurement techniques and automation. These departments organize conferences, cooperate with scientific and technical literature publishing houses, take part in international conferences, etc.

The department of metrology and precision mechanics of the SIMP organized in 1958 a large conference on problems of precision mechanics and the techniques of measurements, in which foreign specialists also participated. This conference discussed the present state of Polish measurement techniques and formulated the most important tasks for its development.

A special technical literature is very important for the development of measurement techniques. In 1955 there appeared a new journal entitled "Measurements, automation and control" ("Pomiary, automatyka, kontrola") which deals with measurement techniques, automation, precision mechanics, optics and technical inspection.

In 1950 the Chief Measures Administration organized center for the collection of data on metrology. This center established a card index of annotations of articles in the sphere of measurements, which appeared in metrological and other technical and scientific publications (in all 140 titles). The card index now consists of

almost 25,000 cards. An information service on new publications has been organized and photographic copies of the articles in the index are dispatched on request.

The Chief Measures Administration cooperates with international metrological organizations (the International Bureau of Weights and Measures, the International Organization of Juridical Metrology) and metrological services of several countries.

An especially close contact is maintained with the metrological services of other socialist countries and in the first place those of the USSR.

In cooperation with the Soviet Union and the Hungarian People's Republic, Poland was the initiator of the international conference on measures held in Budapest in 1958.

In their activity the workers of the Chief Measures Administration take advantage of the experience gained by the metrological and inspection organizations of the USSR and the countries of people's democracy.

As the result of the decisions adopted by the 4th Plenum of the Central Committee of the Polish United Workers Party held on January 20-22, 1960, which dealt with the relations between science and production, training of personnel, planning and coordination of design and scientific work, international scientific and technical collaboration, the workers of the measurement service of People's Poland are faced with important tasks. An efficient execution of these tasks by the workers of the Chief Measures Administration will promote the speedy development of the national economy and technical progress in Poland.

# LINEAR MEASUREMENTS

## A DEVICE FOR AUTOMATIC COMPENSATION OF TEMPERATURE ERRORS IN MEASURING LENGTHS

A. V. Vysotskii, P. P. Antonov, and A. P. Kurochkin

Translated from Izmeritel'naya Tekhnika, No. 6, pp. 9-10, June, 1960

The error due to variations in dimensions of large articles, caused by temperature changes, affects the accuracy of their measurements.

The existing practice of keeping both the measuring instrument and the component under test in the same ambient temperature for a long period of time, preceding the measurement with the object of equalizing their temperatures, requires considerable expenditure of time, thus making this method unsuitable for measuring equipments built into automatic lines, especially when machining large details. This method is completely unsuitable for production control.

The device for automatic compensation of temperature errors, described below, and developed by the Interchangeability Bureau (type BV-1029 and BV-1087) for use with a relatively simple and reliable pneumatic method of measurement, which makes it easy to carry out such measurements as determining the sum or difference of two dimensions, the mean diameter of two or several samples, etc.

The sensitive elements used in this device consisted of miniature thermovaristor beads type EMT-1, which possess very small inertia.

Each thermovaristor is fixed respectively to the commodity under test and the bracket (or stand) of the measuring instrument.

Both thermovaristors $T_1$ and $T_2$ are connected to the arms of a self-balancing bridge (Fig. 1). The other two arms consists of resistors $R_1$ and $R_2$ and portions of slide wire R. The output diagonal of the bridge between point 1 and the slide wire moving contact 2 is connected to the input of amplifier A. The bridge is fed with 1.5 v at the mains frequency.

The output of the amplifier is connected to one of the windings of servomotor M which displaces the slide wire contact in the required direction until balance is obtained. In a given temperature range the position of the slide wire contact is proportional to the temperature difference between the measuring instrument and the object under test.

The resistors $R_3$ and $R_4$ are used in order to make the thermovaristors interchangeable, since their characteristics vary.

The dimension of the detail is measured by means of a pneumatic differential instrument 1 (Fig. 2). Nozzles 2 which measure articles 3 are connected into one branch of the instrument, and nozzles 4 which are placed opposite wedge 5 are connected by means of a rack and pinion transmission to the slide wire contact 6, and form the other branch. When the temperature difference between article 3 and bracket 7 of the measuring instrument changes, the servomotor displaces the contact and with it wedge 5 thus changing the gap under nozzles 4. Hence, the pressure in the right-hand side of the instrument is thus changed.

The angle of the wedge is selected according to the nominal size of the article in such a manner that variations in the total gap of nozzles 2, due to changes in the temperature difference between article 3 and

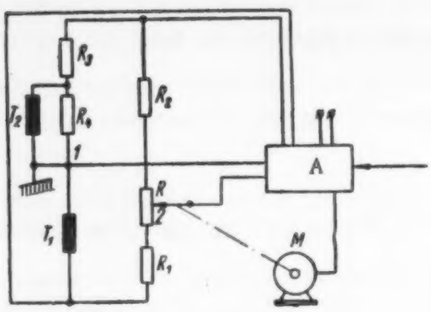



Fig. 1.

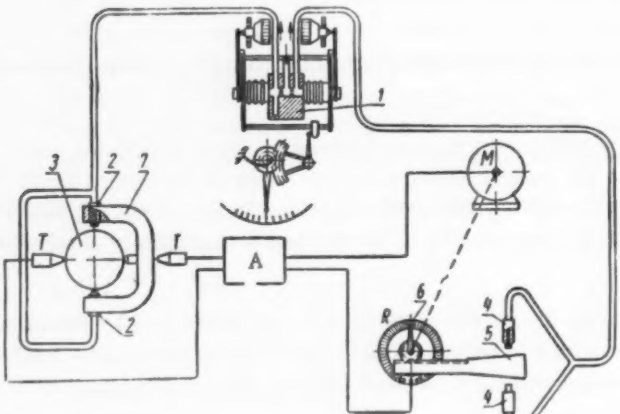



Fig. 2.

bracket 7, correspond to an exactly similar variation both in size and direction of the total gap of nozzles 4, due to the displacement of wedge 5, which corresponds to the above temperature difference.

In such a case the readings of instrument 1 will remain unchanged, despite the actual variation in the size of the article (or the bracket or both the article and the bracket). Hence, in a certain temperature range the readings of the instrument will depend only on the size of the article referred to a constant temperature.

The efficiency of this arrangement has been tested out experimentally. From the characteristics of the available thermovaristors the values of their resistances were calculated in the temperature range of +10 to +30°C.

A characteristic of the compensation wedge displacement with respect to the temperature differences and the nominal temperature was obtained from the calculated resistance values by using resistance boxes. This characteristic was practically linear, i.e., the wedge displacements were proportional to the differences of temperature, which is very important since the variation in size due to heating is also proportional to temperature.

Next the measuring and compensating circuits were tested out as a whole. For this purpose an optimeter and two measuring nozzles fixed to a bracket, were mounted on the stand of a vertical optimeter. The detail under test, which consisted of a 300 mm block gauge, was placed on the table of the optimeter and heated up by means of a current passed through a wire wound helically round the gauge.

The thermovaristors of the compensating circuit were fixed to the optimeter stand and the block gauge. In addition the temperature of the stand was measured by means of a mercury thermometer, and that of the gauge by means of a clinical thermometer.

The dimensions of the gauge were measured by means of a pneumatic bellows transducer BV-N974.

The tests showed that after the temperature over the entire length of the gauge was equalized the automatic temperature compensation eliminated almost completely the temperature error in measurements. For instance, the pneumatic transducer measured a deviation of 1.5 $\mu$ from its readings at normal temperature when the size of the block gauge as measured on the optimeter changed by 60 $\mu$.

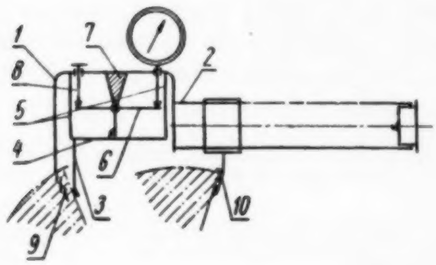
# A PITCH GAUGE FOR WORM-GEAR CUTTERS

N. G. Klyuchnikov

Translated from Izmeritel'naya Tekhnika, No. 6, p. 10, June, 1960

The hand-operated pitch gauge which is described below serves to measure the circular pitch of worm-gear cutters during their manufacture or sharpening on grinding machines and provides measurements on the spot without taking the cutter out of the machine.

With the help of exchangeable arms it is possible to measure cutters with modules from 1 to 30 mm.




The pitch gauge consists of (see figure) a head with a lever mechanism and a guide over which travels an elastic expansion bushing together with a rigid arm.

Bracket 1 is rigidly fixed to guide 2 by means of a screw and a stop. The measuring contact 3 is rigidly fixed to the swinging cleat 4 which is connected to the bracket by means of flat springs 5, which make it possible for the cleat to swing gently to the left and right.

The swinging cleat 4 is provided with a projection, which touches by means of a ball contact a T-shaped lever 6 making it turn about a swivel rest 7. The horizontal ends of the lever beam are connected at one end to a clock-type indicator and at the other to detent 8; thus the movement of the measuring contact is related to the indicator readings.

The free end of the bracket is fixed to a stationary rest arm 9, which touches with its flat surface the upper part of the cutter's tooth and with its two side balls the side profile of the tooth,thus determining precisely the position where the measuring contact ball touches the machined surface of the cutter tooth.

The mobile rest 10 fixed to the elastic bushing is displaced along the guide rail and rests against the neighboring tooth of the cutter at three points: at the upper part of the tooth and the frame along the profile of the tooth by means of its flat surfaces and against the machined surface of the tooth by means of its ball contact.

In order to measure the pitch of the cutter the indicator is placed on zero at one tooth and further measurements of deviations are read off the indicator.

The pitch gauge for worm-gear cutters can find a wide application in engineering factories.

# AN INDICATING INSTRUMENT FOR CHECKING GEAR CUTTERS

V. N. Levitskii

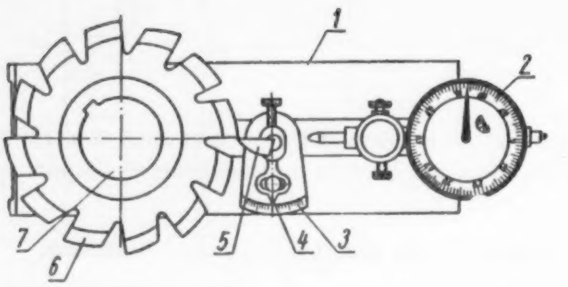
Translated from Izmeritel'naya Tekhnika, No. 6, p. 11, June, 1960

Disk gear cutters are mainly used for individual and repair work.

They do not require a special tooth cutting equipment and they can be used on ordinary milling machines provided with a universal dividing head or any dividing device.

In order to obtain a correct evolute profile for the gear tooth being cut, with the required finish of the surface, it is necessary to adhere strictly to the geometrical dimensions of the cutting tool.

The cutting angle of disk cutters are similar to those of profile cutters: the leading angle for rough cutters is normally taken to be 8-10°, for finishing cutters is 0° and the back angle is 10-15°.




The workshop measuring instrument developed by the test laboratory of the "Vulkan" plant provides the checking of four parameters of the cutter at the machined portion: deviations from a radial shape of the forward cutting edge, radial wobble, variations in the relieving portion and the back angle.

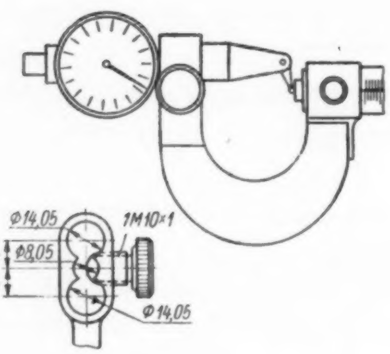
Base 1 of instrument has a groove (see figure) in which a stand slides along the axis and serves to carry an indicator 2. A bushing which carries sector 3 calibrated in degrees also slides in the groove. The bushing also carries an indicator with a pointer 4 and knife 5 which is set to the required height and approaches to the angle of the disk gear cutter 6 under test, mounted on mandrel 7.

The instrument is supplied with spare mandrels of 16, 22, 27 and 32 mm in diameter, designed for the mounting hole of various disk cutters.

The instrument can be used for checking disk gear cutters and cutters for making twist drills, reamers, taps, countersinks, as well as various profile disk cutters for making machine parts.

## A DEVICE FOR CHECKING INDICATORS

N. K. Ochinskii (the Zaporozh'e State Inspection Laboratory for measurement equipment) and A. P. Nikonorov (Rybinsk) report a successful use of a device for checking indicators with graduations of 0.01 mm (see fig.).




A special holder with three holes is fixed instead of the anvil to a micrometer grade 0, with a range of 0-25 mm. The clock type indicator is fixed in the center holes by means of screw and lever type indicators are fixed in the outside holes.

The use of this device increased the productivity of labor in checking indicators.

# MEASUREMENTS OF TIME

## TIME AND FREQUENCY STANDARDS

V. F. Lubentsov

Translated from Izmeritel'naya Tekhnika, No. 6, pp. 12-17, June, 1960

Owing to the peculiar development of life on earth, time calculations were connected with the rotation of the earth about its axis and the duration of the mean day and night was taken as the standard of time, which was reproducible by means of astronomical observations.

With the development of science and technology the time between astronomical observations started being kept by means of pendulum, and later, quartz clocks, which greatly increased the accuracy of time-keeping as compared with the astronomical observations. This development brought to light the uneven rotation of the earth and made it possible to obtain a more uniform time scale than the one obtainable from direct astronomical observations. The establishment of atomic and molecular frequency standards led to the necessity of changing over to a more uniform time standard than the ephemeris time. In practice uniform time can be obtained from photographic observations of the moon [1] and determinations of the astronomical time TU-2, providing there exists a clock which can produce a uniform time scale during a considerable time in order to be able to observe the irregularities in the rotation of the earth [2].

In modern time services the basic time keepers consist of groups of quartz clocks whose frequency is controlled by atomic or molecular frequency standards. It is interesting to examine the errors of these clocks, the reasons for their appearance and conditions which have to be fulfilled when they are controlled by means of molecular generators (clocks) in order to obtain the most uniform time scale.

Constancy of the frequency of quartz and molecular generators. The variations of the frequency of quartz and molecular generators is due to the presence of various fluctuations (noise) and change in the parameters of the circuits. In modern generators the value of short random frequency variations due to the presence of noise is considerably smaller than the instability due to changes in the parameters, hence, for the production of the time scale, it is only necessary to examine the parametric stability of the generator frequency.

The variations of the frequency of a quartz generator, without reference to its concrete electrical circuit, can be considered to consist of changes in the frequency of the quartz element proper (as the result of variations of its temperature $T^{\circ}$ and its elastic properties B), and the variations of parameters $P_1 \ldots P_n$ which affect the frequency of the quartz element (conditions of fixing in the holder, pressure, diameter of the electrodes, size of the circuit components which excite the quartz element, and the conditions of its operation).

Thus, the frequency of oscillations of the quartz generator $f_q$ is a complex function of a large number of variables

$$f_q = \varphi\,(T^{\circ}, B, P_1, \ldots P_n). \tag{1}$$

The total relative error of the quartz generator frequency $\gamma_{rq}$ with the variation of all the parameters is

$$\begin{gathered}\gamma_{rq} = \alpha_{T^{\circ}} \frac{dT^{\circ}}{T^{\circ}} + \alpha_B \frac{dB}{B} + \alpha_{P_1} \frac{dP_1}{P_1} + \ldots + \alpha_{P_n} \frac{dP_n}{P_n};\\ \alpha_{T^{\circ}} = \frac{\partial f_q}{\partial T^{\circ}} \cdot \frac{T^{\circ}}{f_q};\ \alpha_B = \frac{\partial f_q}{\partial B} \cdot \frac{B}{f_q};\\ \alpha_{P_1} = \frac{\partial f_q}{\partial P_1} \cdot \frac{P_1}{f_q};\ \alpha_{P_n} = \frac{\partial f_q}{\partial P_n} \cdot \frac{P_n}{f_q};\end{gathered} \tag{2}$$

$\alpha_{T°}$, $\alpha_B$, $\alpha_{P_1}$, . . . $\alpha_{P_n}$ are the relative changes in the frequency of the generator when the relative values of each parameter is changed separately.

When the relative changes in the value of each parameter are small and the values of $\alpha_{T°}$, $\alpha_B$, $\alpha_{P_1}$, $\alpha_{P_n}$ remain constant we obtain from (2)

$$\gamma_{rq} = \sum_{i=T°,\,B} \alpha_i \frac{\Delta i}{i} + \sum_{q=1}^{n} \alpha_q \frac{\Delta P_q}{P_q} \tag{3}$$

The first summation of (3) characterizes the generator frequency error due to changes in the quartz element proper, and the second summation.errors due to variations in all the parameters.

In the majority of cases it is very difficult to find general expressions of $\alpha_i$ and $\alpha_q$ mathematically, but they can be found experimentally.

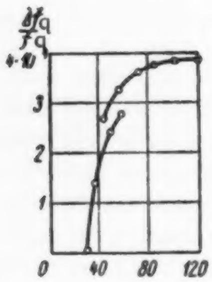



Fig. 1.

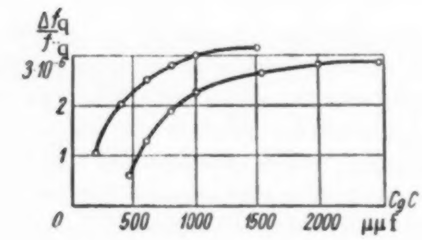



Fig. 2.

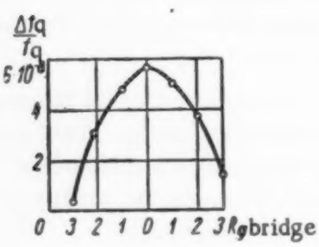



Fig. 3.

Figure 1 shows the relation of the oscillation frequency of a quartz element,made in the shape of a bar to the diameters of the electrodes [3]; Fig. 2 shows the graph of the relation of $\Delta f_q/f_q$, for one of the versions of an RC generator circuit, to the capacity $C_g$ in the control grid circuit and $C_k$ in the cathode of the oscillator tube; Fig. 3 gives the relation of $\Delta f_q/f_q$ to the temperature of the quartz element. From these and similar graphs it is possible to determine the value of coefficients $\alpha_i$ and $\alpha_q$ for given values of $\Delta i/i$ and $\Delta P_q/P_q$ , and solve (3).

In order to obtain the minimal value of the maximum error it is necessary to find the conditions for which each term in (3) has its minimum. Since not all the variables in (1) are independent, it is possible to compensate some of the variations by means of others, or find the minimum for some of the terms which are considerably larger than the others, and select them in such a way as to make $\gamma_{rq}$ minimum.

The characteristic of $\Delta f_q/f_q$ with respect to the parameters depends on the Q factor of the quartz element; a quartz oscillator with a low Q factor stops oscillating at smaller values of $C_g$ and $C_k$. Hence,highly stable quartz generators require quartz crystals with a high Q which do not change their elastic properties with time, and require holders and generators whose parameter variations with time do not affect the value of $f_q$.
In order to decrease these variations the temperature of quartz elements is normally controlled as well as the supply voltage and other parameters. These measures provide a considerably more stable $f_q$, which then mainly depends on the instability of the quartz element itself.

The variation of the frequency of the molecular generator $f_m$ is also a complex function of many variables; in this case the largest effect is provuced by the variations in the tuning of the cavity circuit, the intensity of the molecular beam, and the focusing of the voltage. The variations of these parameters make $f_m$ deviate from the resonance frequency of molecular absorption and make it vary with time. The value of the total relative error of

the molecular generator frequency $\gamma_{rm}$ can be determined from an expression similar to the one given in (3). It should be noted that the molecular generator has an important peculiarity. The inversion transition frequency in a molecule is not subject to variations with time; hence the first summation in (3) will be zero and

$$\gamma_{rm} = \sum_{q-1}^{n} \alpha_q \frac{\Delta P_q}{P_q}. \qquad (4)$$

The effect of the cavity circuit tuning on $f_m$ can be reduced to a very small value by means of coupled circuits with the required coupling coefficient [4]. Moreover, the middle portion of the phase characteristic of the coupled circuit has a part over which the phase of the oscillations remains constant and the detuning from the resonance curve in its middle portion does not lead to a variation of the molecular generator frequency [5].

For the ammonia line I = k = 3, with the cavity circuit tuned to a frequency approaching that of the inverse transition, the relation of $\Delta f_m / f_m$ to the pressure in the source of the molecular beam and the voltage of focusing [6, 7] can be of the same nature as that shown in Fig. 2.

The use of ammonia line I = 3, k = 2, or I = k = 3, for ammonia with a nitrogen isotope, excludes quadripole interaction and hence a superfine structure of spectral lines, and makes it possible to decrease considerably the effect of the molecular beam intensity and the value of the focusing voltage [8, 9] on the ratio $\Delta f_m / f_m$.

The use of a definite type of oscillation in the cavity circuit and of two opposing molecular beams reduces considerably the broadening of the spectral line owing to the Doppler effect [10, 11]. A symmetrically placed coupling slot in the cavity circuit, parallelism of molecules in the beam and some other conditions are also required for the same purpose. The frequency of oscillation of the molecular generator also depends on the matching of the cavity circuit with the waveguide and on the power taken by the latter from the cavity circuit.

The peculiarity of the molecular generator consists in the large value of the natural Q factor of the inverse transition oscillations of an ammonia molecule as compared with the Q factor of quartz elements, which in conjunction with the lack of long-term variation in the inverse transition oscillations in a molecule make the application of the molecular generator a promising procedure for the keeping of a precise time and frequency.

However, in view of the fact that $f_m$ is affected by the variation of many parameters, it is essential in designing molecular clocks to use automatic control of the generator's basic parameters. Only thus will it be possible to obtain a high-frequency stability over a long period.

The use of molecular generators for keeping time and frequency. As was stated above $f_q$ and $f_m$ vary with time according to a very complex law. The form of the function $f = \varphi(t)$ for each type of generator and each generator is different.

For quartz generators the form of the function is determined by the quality of the quartz element and the instability of the remaining parameters, for the molecular generator, by the instability of the generator parameters. The use of generators as keepers of time or frequency is somewhat different. In the case of preserving a frequency, similar to the case of most physical values, it is always necessary to ensure that the generator frequency does not deviate from the set value by more than the maximum error $\gamma_{max}$.

The generator frequency can be represented in the form

$$f_n(t) = f_s + \gamma_n(t), \qquad (5)$$

where $f_s$ is the nominal value of the oscillation frequency; $\gamma_n(t)$ is the oscillation frequency error.

When the generators are used as continuously operating clocks, the readings $Z_n$ of these clocks is determined by the expression $Z_n = \int_0^t f_n(t)\,dt$ providing that the instant t = 0 is taken for the beginning of counting.

From (5) it is possible to determine the error $S_n$ of the clock (the terminology used for the error is nominal)

$$S_n = Z_n - Z_s = \int_{t_n}^{t_{n+1}} \gamma_n(t)\,dt, \qquad (6)$$

where $Z_s = f_s t$ is the reading of the standard clock for time interval $t = t_{n+1} - t_n$; $t_n$, $t_{n+1}$ are instants of the count.

In the case of time-keeping it is important that every instant of time should correspond to a time on the uniform scale. For this purpose it is necessary, as will be seen from (6), that

$$\int_{t_n}^{t_{n+1}} \gamma_n(t)\,dt = 0. \qquad (7)$$

For integral measurements of the generator oscillation frequency against a standard frequency its error is equal to [12]

$$\gamma_n = \frac{n}{t},$$

where n is the number of cycles by which the generator under test differs from the standard one during time t.

The error of the clock $S_n = n/f_n$.

When measuring $\gamma_n$ and $S_n$ in equal adjacent time intervals, it is possible to determine:

a) the change in the generator frequency error:

$$\Delta\gamma_n = \gamma_n' - \gamma_n = \frac{\Delta n}{t}; \quad \Delta n = n' - n;$$

b) the change in the clock error $\Delta S_n = S'_n - S_n = \Delta n/f_n$;

c) the variation of the generator frequency error;

$$\delta\gamma_n = \Delta\gamma_n' - \Delta\gamma_n = \frac{\delta n}{t}; \quad \delta_n = \Delta n' - \Delta n;$$

d) the variation of the clock error $\delta S_n = \Delta S'_n - \Delta S_n = \delta_n/f_n$.

Taking into consideration that $\gamma_n = f_n - f_s$ and $S_n = Z_n - Z_s$, we obtain the equality

$$\Delta\gamma_n = \Delta f_n;\ \delta\gamma_n = \delta f_n;\ \Delta S_n = g_n;\ \delta S_n = V_n, \qquad (8)$$

where $\Delta f_n$ and $\delta f_n$ are the change and variation of the generator frequency; $g_n$ is the change in the clock error; $V_n$ is the variation of the clock error.

All the above errors can be considered as relative values with respect to the nominal value of frequency $f_s$ and the interval of time between adjacent readings of the clock:

$$\gamma_{rn} = \frac{n}{tf_s} = S_{rn};\ \Delta f_{rn} = \frac{\Delta n}{tf_s} = g_{rn};\ \delta f_{rn} = \frac{\delta n}{tf_s} = V_{rn}. \qquad (9)$$

It follows from the above that integral changes in the oscillation frequency and the direct comparison of clocks give the same results.

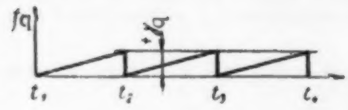


Fig. 4.

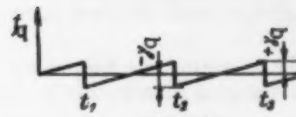


Fig. 5.

From systematic adjacent measurements it is possible to calculate the preliminary values of errors (9) for definite time intervals (24 hours, one hour, one minute); which can be checked after the lapse of a considerable time by astronomical observations [13] as mean values over a long period.

Since the calculation of accurate values of $\Delta\gamma_n$ and $\delta\gamma_n$ are possible only for the past, and the time service and frequency determination require accurate values of these quantities at any given moment, the existence of time-keeping clocks, which can produce the most uniform scale, is of great importance.

The molecular generators used to date had a very restricted time of continuous operation, thus complicating their use in continuously working clocks and made it necessary to use quartz clocks for the purpose of providing a continuous reference for controlling frequencies over an extended period of time [7]. This control can be used for the following purposes.

a) For determining the error of quartz clocks. If at instant $t_1$ the error of a quartz generator was $\gamma_1$ and at instant $t_2-\gamma_2$, then according to (6) during the time interval $t_2-t_1$ the quartz clock has an error of

$$S_{q_1}=\frac{(\gamma_2+\gamma_1)(t_2-t_1)}{2f_s},$$

where $f_s$ is the nominal value of the oscillation frequency at which $\gamma_1$ and $\gamma_2$ were measured.

The error of the quartz clock in the subsequent instant $t$ can be determined from the following equation:

$$S_{q_i}=\frac{1}{2f_s}\sum_{i=1}^{n}(\gamma_i+\gamma_{i-1})(t_i-t_{i-1}). \tag{10}$$

The reading of the quartz clock $Z_{qi}$ can be found from the equality

$$Z_{q_i}=Z_{q_1}-\frac{1}{2f_s}\sum_{i=1}^{n}(\gamma_i+\gamma_{i-1})(t_i-t_{i-1}). \tag{11}$$

where $Z_{qi}$ is the reading of the clock at instant $t_1$.

Expressions (10) and (11) hold only for linear variations of $f_q$ with time.

b) For a periodic tuning of $f_q$ to $f_m$ by direct changing of $f_q$ or by additional shifting of the frequency of these oscillations by means of a device for a continuous, uniform changing of the phase of oscillations in such a manner that the frequency-difference oscillations are made to equal zero within the accuracy of measurements.

Figure 4 shows the graph for tuning $f_q$ at instants $t_1$, $t_2$, $t_3$ and $t_4$ and it is assumed that the variations of $f_q$ are linear when the error of the clock can be calculated. It follows from the graph that this method of tuning can be used when $f_q$ is employed for frequency measurements and it is important to keep $\gamma_q$ below a certain value.

c) For periodic tuning of $f_q$ to $f_m$ by compensating for the changes in $f_q$.

It follows from Fig. 5 that this method of tuning can be carried out by means of changing $f_q$ by a value equal to $2\gamma_q$. The duration of the interval between retuning instants should be selected to satisfy equation (7). In addition to the advantages with respect to the frequency measurements (similar to the preceding method) in

the case when the variations of $f_q$ are linear with time, it becomes possible to obtain almost a uniform time scale by taking into consideration the nonuniform readings of the clock within the time intervals between the tuning instants.

The error in tuning the frequency $\gamma_n$ of a quartz generator must satisfy the following relation:

$$\Delta\gamma_q > \gamma_n = \sqrt{\delta\gamma_m^2 + \delta\gamma_q^2 + \gamma_u^2}. \tag{12}$$

where $\delta\gamma_m$ is the random error of $f_m$; $\Delta\gamma_q$ is the systematic error of $f_q$; $\delta\gamma_q$ is the random error of $f_q$; and $\gamma_u$ is the error of measurement of $f_q$ against $f_m$.

Frequency methods of measurement give an error such that $\gamma_u \ll \delta\gamma_q$, and if it is taken into account that $\delta\gamma_m < \delta\gamma_q$ it becomes possible to assume that for precise tuning it is necessary in the first place to obtain $\delta\gamma_q < < \Delta\gamma_q$. The best modern quartz generators have systematic day-to-day frequency variation errors of the same order as the random frequency variation for the same period; thus actual generators have a nonlinear variation of $f_q$ with time, and, hence, in order to determine $\Delta\gamma_q$ it becomes necessary to extend the spacing between frequency adjustments, thus limiting the accuracy of the clock.

In order to determine the value of $\Delta\gamma_q$ (providing that $\Delta\gamma_q$ and $\delta\gamma_q$ are of the same order of magnitude), it is possible to measure $f_q$ and $f_m$ more often than adjusting the frequency. Such measurements may disclose the actual nature of $f_q$ variations with time without extending appreciably the interval between adjustments and thus provide a greater tuning precision.

The defect of the adjustment (or calculation) method is the discrete nature of the data thus obtained, as the result of which it is impossible to obtain a complete picture of the $f_q$ variations so as to be able to approach the time scale of the quartz clocks to a uniform one. Since the accuracy of the frequency adjustment is largely determined by the value of $\delta\gamma_q$, the error of adjustment will not greatly decrease with smaller values of $\Delta\gamma_m$ and $\delta\gamma_m$, thus making it impossible to utilize the greater stability of $f_m$ for raising the precision of time and frequency registration.

The advantage of the periodic tuning of $f_q$ and $f_m$ is the possibility of periodically connecting the molecular generator, thus greatly simplifying their application. This advantage is of a temporary nature and is due to the imperfect operational properties of present-day molecular generators.

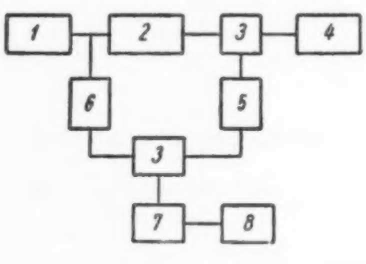



Fig. 6. 1) Quartz generator; 2) multiplier; 3) mixer; 4) molecular generator; 5) intermediate-frequency amplifier; 6) converter of the quartz generator frequency to the intermediate frequency; 7) difference-frequency divider; 8) difference-frequency counter.

The most promising method of utilizing the stability of the molecular generator frequency for the purposes of the state time and frequency service is their use as continuously operating molecular clocks. Such clocks may be constructed in the following ways.

1. Division of the oscillation frequency of molecular generators down to 1 kc. At the present time this method is in practice very difficult to achieve since the division of ultrahigh frequencies has not been sufficiently well studied as yet.

2. Automatic frequency control (AFC) of $f_q$ against $f_m$ [14]. The operation of this system consists in reducing all the variations of $f_q$, due to any factors, which change the frequency of the quartz generator by $\Delta f_{qn}$ (for an open-loop control system) to the value of the residual variation of $\Delta f_{qr}$ (for a closed-loop control system). The AFC system cannot completely compensate for the initial variations of the controlled generator oscillation frequency, it can only reduce them by a factor of $k = \Delta f_{qn}/\Delta f_{qr}$ [15]. Since in the presence of long-term variations of $f_q$-$\Delta f_{qr}$ the function of time will have the sign of these variations, it will lead according to (6) to clock errors, which will be proportional to the time of their continuous operation.

The AFC system provides an improvement in the stability of quartz clocks expressed by a factor of k is determined by the limit of stability of the control system), which cannot provide with a further increase in the stability of $f_m$ a considerable improvement in the approximation of the time scale of these clocks to a uniform scale.

3. Automatic phase control (APC) of $f_q$ against $f_m$. The operation of this system is based on the fact that variations in the phase of quartz generator oscillations due to various factors in an open-loop control system are greatly reduced in a closed-loop system, providing these variations do not exceed the hold-in range of the system. The adjustment is carried out by changing the phase of the quartz generator oscillations in a direction opposite to the original change which is determined by the phase difference $\varphi_m$ between the multiplied frequency of the controlled quartz generator and that of the molecular generator.

If we assume that $\varphi_m \leq 90°$, the APC can introduce an additional relative error into $f_q$ for various time intervals as shown in column 1 of the table below.

| Source of additional error | Spacing of measurements | | |
|---|---|---|---|
| | 1 sec | 5 min | 24 hrs |
| APC-1 (first case) | $1\cdot10^{-11}$ | $3.3\cdot10^{-14}$ | $1.2\cdot10^{-16}$ |
| APC-2 (second case) | $1\cdot10^{-9}$ | $3.3\cdot10^{-12}$ | $1.2\cdot10^{-14}$ |
| Multiplier | $1\cdot10^{-9}$ | $1\cdot10^{-11}$ | $3\cdot10^{-13}$ |
| APC-2 and multiplier | $2\cdot10^{-9}$ | $1.3\cdot10^{-11}$ | $3.1\cdot10^{-13}$ |

The phase instability of frequency multipliers introduces into the controlled quartz generator frequency additional errors whose estimated values are shown in line 3 of the table, and which can produce instability in the operation of the entire system. In order to increase the reliability and stability of operation of the APC it is possible to check it against several oscillations of a molecular generator, for instance, 100 oscillations instead of one, and the maximum relative additional error in $f_q$ can have the value shown in line 2 of the table.

On the basis of the preliminary information on the maximum additional errors of the APC system it is possible to arrive at the conclusion that owing to the phase variations in the multipliers of $f_q$ and the phase instability in the APC system an additional error in the molecular clock of the order of $3\cdot10^{-13}$ during 24 hours is possible.

The APC system provides clocks whose error for long periods of time (months or years) is determined in practice by the error in $f_m$ only, since the additional errors (due to the APC system and multipliers) decrease inversely proportionately to the spacing of measurements. It is possible to assume that for short intervals of time (seconds or minutes) the value of the $f_q$ instability will in practice be smaller than these values in the table, due to the inertia in the variation of the frequency of quartz generators which have a sufficiently high Q factor.

4. Integral measurements of $f_q$ and $f_m$ can be carried out by means of a continuous count of the number of periods in the difference frequency between $f_q$ and the divided frequency $f_m$ or between $f_m$ and the multiplied frequency $f_q$.

The first case is not feasible technically owing to the difficulty of dividing ultrahigh frequencies.

The second case gives a relative error of measurements for 24 hours amounting to $2\cdot10^{-16}$, providing that the error of measuring the number of periods of the difference frequency does not exceed one period per 24 hours. The error in counting the number of periods should be made smaller than the additional error in $f_q$ due to phase instability by counting the number of periods after the difference frequency has been divided (Fig. 6).

In practice it is advisable to take for such measurements the mean frequency of a group of quartz generators thus increasing the accuracy and reliability of determining the error of quartz clocks and providing the possibility of having analytical molecular clocks.

The error of such molecular clocks is determined by the stability of $f_m$, the additional error due to the phase instability of the $f_q$ multiplying circuits and the error of integral measurements which can be made sufficiently small.

## SUMMARY

1. A periodic adjustment of $f_q$ against $f_m$ represents the first stage of application of molecular generators for controlling and checking $f_q$, when it was necessary to keep that frequency within certain measurement limits $\gamma_q$, thus satisfying the frequency measurement requirements. For the purposes of time-keeping the use of this method is not promising since it does not ensure the use of molecular clocks with an error limited to the error of molecular generators, especially if the stability of $f_m$ is further increased.

2. Of the various methods of continuous automatic adjustment or measuring of $f_q$ against $f_m$, the APC system and integral measurements are preferable since they provide actual and analytical molecular clocks with an error which is determined over a long time period by the error of $f_m$, thus providing the most uniform time and frequency scale.

3. The raising of the stability of $f_m$ over a long period of continuous operation can be achieved in the first place by decreasing the effect of the molecular generator parameters, by making the generators work under optimum conditions and controlling automatically the values of these parameters, i.e., the temperature of cavity circuits, voltage of the focusing device and beam pressure.

4. One of the basic requirements of a molecular as well as any other clock is its continuous prolonged operation. The simple conditions of their utilization make molecular clocks suitable for use in the time and frequency service for the purpose of keeping reference time and frequency. In this connection any further development of molecular generators should be aimed at eliminating the use of frozen ammonia and of continuously operating prevacuum pumps.

5. Further improvements in molecular clocks may lead to their becoming the basic time-keepers, working standards, of time and frequency, whose actual value will be determined from astronomical observations. These measurements are necessary because the oscillation frequency of the molecular generators is unstable and can over a long period of time lead to certain relative errors $S_{rm}$ of the clock. In order to measure this error against the primary standard, the ephemeris time, it is necessary to select a long period of astronomical observations so as to make $S_{rm} \cong 3\alpha_0$, where $\alpha_0$ is the relative error of the astronomical determination of this time interval. If there exist molecular clocks whose relative error over a long period does not exceed $1 \cdot 10^{-11}$, the actual value of their indications would have to be determined, considering the present accuracy of astronomical measurement, over a period of several dozen years.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*See English translation.

# MECHANICAL MEASUREMENTS

## A DYNAMOMETER TABLE WITH A SMALL INERTIA

A. A. Voronin

Translated from Izmeritel'naya Tekhnika, No. 6, pp. 18-20, June, 1960

The dynamometer single-component table, described below, is typical of the instruments used at present for measuring separate components of the cutting force in grinding, planing and other technological operations.

The object of this article is to draw the attention of experimenters to the character and the size of certain errors peculiar to these operations and thus prevent the possible spreading of incorrect methods of their utilization.*

The present author has investigated the characteristic of a typical single-component dynamometer type DOS-1 shown in Fig. 1.

The body of the dynamometer is made out of a single piece of steel, which possesses good elastic properties. Webs 3 of the body connect the upper mobile plate 1 to the lower stationary plate 2. The shape and position of the elastic webs provides the possibility of a relatively easy elastic displacement of the upper plate in the longitudinal direction (in the direction of the measured force).

The elastic displacement of the upper plate is recorded by means of two inductive transducers 5, which are placed inside special nonmagnetic bodies 6 on the lower plate, to the right and left of the common armature, 7, fixed by means of screws to the upper plate.

The sensitivity of the dynamometer can be set by means of screws 4 which alter the initial gaps between the transducers and the armature. Both the transducers and the gaps are securely protected from dust or dirt by means of a cover with a door.

The variation of the above gaps under the action of the grinding forces alters the electrical parameters of the input amplifier bridge, whose adjacent arms consist of the inductive transducers. The recording of the output signal is carried out by means of loop oscilloscope type MPO-2 (vibrator type IV).

The dynamometer is intended for measuring forces in the range of 20-1000 kg-wt; the natural frequency of the dynamometer is about 450 cps; its stiffness in the direction of measurement is j = 45,000 kg-wt/mm.

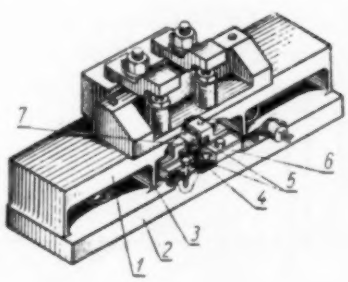


Fig. 1.

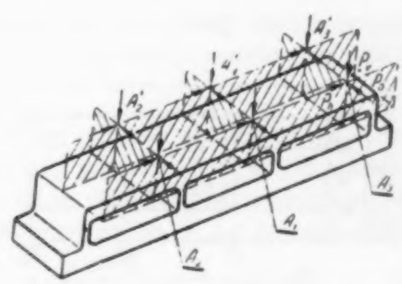

Fig. 2.

*In the books of P. A. Markelov "Speed grinding of steel by face milling machines," and V. V. Kuvshinskii, "Grinding," Mashgiz, 1955, and some other books, incorrect methods of using dynamometer tables are given.

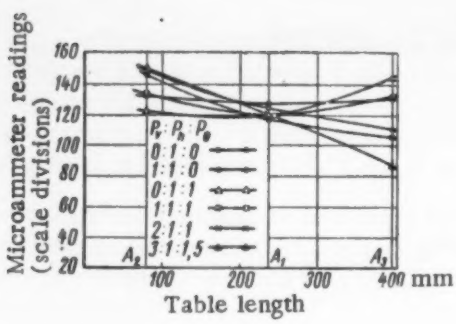


Fig. 3. Variations of the sensitivity of the table along its length ($A_2 - A_1 - A_3$) for $P_h$ = 350 kg-wt.

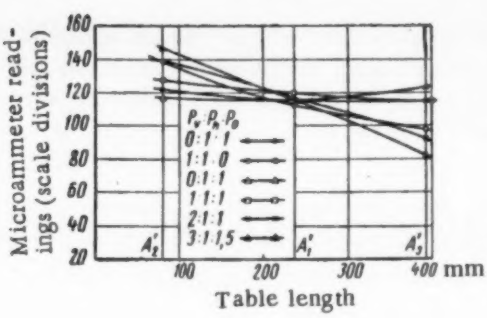


Fig. 4. Variations of the sensitivity of the table along its length ($A'_2 - A'_1 - A'_3$) for $P_h$ = 350 kg-wt.

In order to establish the relation between the nature and value of the dynamometer reading and the load, a special calibrating device was used which made it possible to simulate the above conditions.

By means of this device the dynamometer can be loaded with three static forces applied to various points of the working surface of the table as shown in Fig. 2.

During testing, dynamometer readings were taken for various conditions of loading. From these readings the character and absolute values of the relation of the readings to the load conditions were established.

Figure 3 shows these relations. The readings of the microammeter are plotted along the y axis when force $P_h$ = 350 kg-wt was measured. The load was applied at three points along the length of the table as shown in Fig. 2. In addition, some of the curves correspond to various relations among the components $P_v$, $P_h$ and $P_o$.

The study of the curves shows that if the dynamometer table measures component $P_h$ when the other two components are equal to zero, its sensitivity remains practically constant, irrespective of the displacement of the point of application of the force along the table. In reality the components $P_v$ and $P_o$ are never equal to zero, and can have values relative to $P_h$ shown in Fig. 3. In this instance the sensitivity of the dynamometer varies considerably when the point of application of the force is changed in one direction or the other with respect to the middle of the table. Thus, at point $A_2$ the variation of the sensitivity and, hence, of the error of measurement attains 19%. At point $A_3$ the variations in the reading of the dynamometer amount to ± 25%. A similar type of variation in the dynamometer reading occurs when the point of application of the resultant force is placed in another plane determined by points $A'_1$, $A'_2$ and $A'_3$ (Fig. 4).

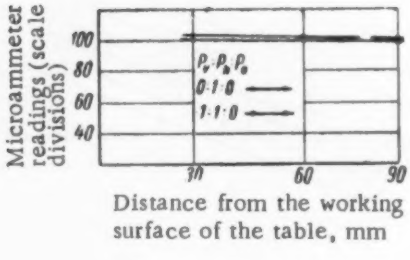


Fig. 5. Loading at point $A_1$ for $P_h$ = 250 kg-wt.

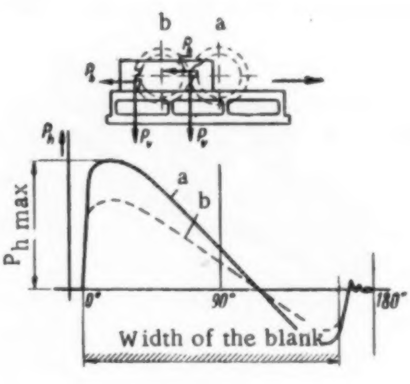


Fig. 6.

Tests have shown that displacement of the point of application of the resultant force in the transverse direction or its displacement away from the surface of the table has hardly any effect on the readings of the instrument (Fig. 5).

On the basis of the properties of the dynamometer table established during testing, the nature of the errors in measuring the force of grinding is illustrated in Fig. 6. The oscillograms a and b correspond to two relative positions of a single-tooth cutter and the blank fixed to the dynamometer. If the oscillograms are deciphered without taking into account the properties of the dynamometer, the measurements will be made very inaccurately. Thus if, for instance, the real relations between the components during recording were equal to $P : P_h : P_o = 2 : 1 : 1$, whereas the calibrations were carried out when $P_v : P_h : P_o = 0 : 1 : 0$, we should obtain an excessively high value of $P_h$. In order to obtain correct data, however, it is not sufficient to use the calibration curve obtained for the relations of $P_v : P_h : P_o = 2 : 1 : 1$. It is necessary to obtain the above curve under conditions of loading (the place of the load application, the relation among components) which correspond to the instant of the recording of forces. Otherwise the measurements will be seen even more successively high, as will be seen from the curves of Fig. 3. Since, however, we do not know the actual relation of the components, and the variations in sensitivity along the table are considerable, we must work, in order to prevent errors, only over a small area in the middle of the table and a length amounting to 50-60 mm. In this case it is possible to calibrate the dynamometer by means of one factor $P_h$ only and the measurement errors will not exceed $\pm 4\%$.

## SUMMARY


The dynamometers type DOS-1, which have a small inertia, are subject to variations in their readings according to the conditions of their use.

The combination of the effects due to the displacement of the point of application of the resultant force within the lengths of the table, and the variation in the relations among the components of the force may lead to measurement errors up to 50% and more. In order to avoid considerable measurement errors it is necessary to keep, during measurements, the point of application of the resultant force within the limits of a portion of the table in its middle and amounting to 0.1-0.15 of its length.

If the above requirements are adhered to, the calibration of the dynamometer can be carried out by the simplest of means, namely by applying one force only in the longitudinal direction. The dynamometer errors in this case will amount to $\pm 4\%$ of the measured value.


# A TWO-COMPONENT DYNAMOMETER WITH AN OPTICAL SCALE


V. I. Melamed and V. I. Davidyuk



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For the purpose of measuring two components of the cutting force in free cutting, the Chelyabinsk Institute of Mechanization and Electrification of Agriculture constructed a two-component dynamometer type DDI-600, which uses instead of micrometers an optical display device.

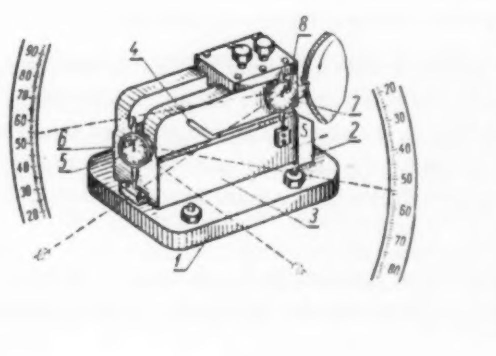


Plate 1, which serves as the base of the dynamometer, carries (see figure) a vertical wall 2 to which body 3 of the instrument is welded. The body has a narrow slot 4, which is horizontal in the front portion of the dynamometer and is slanting in the rear portion.

Under the effect of effort $P_y$ the vertical wall 2 bends and the pointer of the indicator 5 turns, together with its mirror 6, through an angle whose value is determined by the value of the effort $P_y$. A beam of light from the illuminator is reflected from mirror 6 onto scale $P_y$ which is placed at a distance of 2 m from the dynamometer.

Under the effect of force $P_z$ the upper portion of the body to which the cutter is fixed is displaced downward. This is attained by means of slot 4. The displacement of the upper part of the dynamometer with respect to the lower part is recorded by indicator 7, whose pointer carries mirror 8. A beam of light from the illuminator is reflected from mirror 8 onto scale $P_z$ which is also placed at a distance of 2 m from the dynamometer.

Since the inclined portion of the slot 4 is placed at the height of the lathe centers, effort $P_y$ does not affect the reading of indicator 7, and the choice of an appropriate sweep for the cutter makes the reading of indicator 5 independent of the effect of $P_z$.

The dynamometer with the optical display has a strictly linear calibration characteristic. It displayed in use complete reliability at cutter speeds of 30-40 m/min.

Particularly good results were obtained with this dynamometer, owing to its high precision in measuring efforts $P_z$ and $P_y$, when thin turnings were being cut.

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# PROTECTION OF MANOMETERS WHEN MEASURING PULSATING PRESSURES


A. S. Lifshits and I. P. Mandel'berg



Translated from Izmeritel'nayá Tekhnika, No. 6, pp. 20-22, June, 1960


Periodic (pulsating) variations in the pressure of the working substance (gas or liquid) occurs in the operation of many machines. This pressure (its mean value) is measured by a manometer of some type or other consisting of a sensitive element (tube, bellows, diaphragm, etc) and a transmitting mechanism, which actuates a pointer or a remote operating unit. The peculiarity of such instruments consists in the existence of one or several resonance frequencies which produce oscillations of separate components, at a large amplitude when the pulsation frequency coincides with their natural frequency. Usually these oscillations lead to a rise in the measurement errors and even to the breaking of the instrument.

The natural frequencies of the measuring systems which consist of diaphragm electrical transducers of pressure, transmission mechanisms (which may be lacking) and remote transmission units, lie in the range of 500-1000 cps for pressures of 5 to 200 kg-wt/cm$^2$.

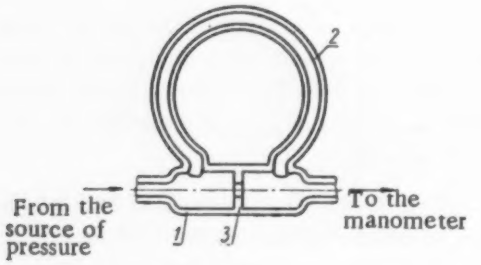


Fig. 1.

In order to avoid oscillations, manometer pointers are supplied with dampers usually consisting of chambers, with one or several diaphragms whose holes vary in size according to the required degree of damping.

The defect of such a damper consists in the residual pointer pulsations which normally cannot be eliminated since a large decrease in the size of diaphragm holes would lead to a far too large lag in the instrument readings and would increase the probability of the holes becoming blocked with dirt.

The author of this article has proposed a damper (Fig. 1) which will protect the manometer from pulsating

pressures. The damper consists of a chamber 1 with diaphragm 3 and a pipe 2, which connects the two cavities of the damper otherwise separated by the diaphragm. The dimensions of the chamber with the diaphragm and the pipe are selected in such a manner that their amplitude-frequency characteristics in the range of the resonance frequency of the manometer are similar. With a correctly selected length of the pipe the phase shift in it is such that the pressure oscillations at the fundamental resonance frequency of the manometer, having passed through the pipe, arrive at the diaphragm in phase opposition to the original oscillation and suppress them.

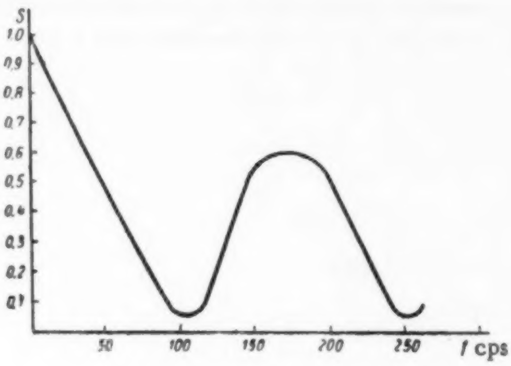


Fig. 2.

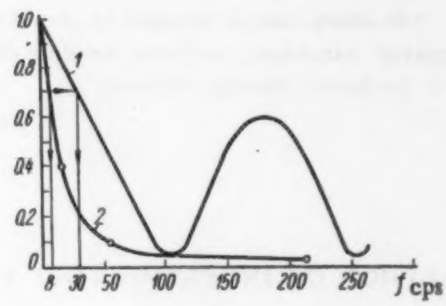


Fig. 3. 1) The amplitude-frequency characteristic of the damper with an additional pipe, $\omega_1 = 188.4\ \sec^{-1}$; 2) the amplitude-frequency characteristic of a damper with a diagram, $\omega_2 = 50.24\ \sec^{-1}$; $\tau_2/\tau_1 = 3.77$.

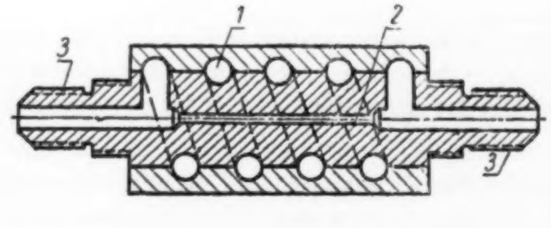


Fig. 4. A version of the damper design with the additional pipe. 1) Pipe, 2) capillary diaphragm, 3) connecting pipe.

The phase shift $\varphi$ provided by pipe 2 is represented by

$$\varphi = 180^\circ + \varphi_p, \tag{1}$$

where $\varphi_p$ is the phase shift of the pressure oscillations which have passed through the chamber with the diaphragm characterized by the transfer constant $S = 1/(1 + j\omega\tau)$ ($\tau$ being the time constant of the diaphragm).

Since the maximum value of $\varphi_p$ can vary from 0° (the ideal case of gas transmission without friction) to 90°, it is possible for $\varphi$ = 180 to 270°. The required length of the pipe is determined from formula

$$l = \frac{\varphi}{360}\lambda = \left(\frac{1}{2} \div \frac{3}{4}\right)\lambda, \tag{2}$$

where $\lambda$ is the length of the sound wave equal to $c/f_0$; c is the speed of sound; $f_0$ is the resonance frequency of the manometer.

Thus, the frequency characteristic shown in Fig. 2 is obtained; the characteristic was obtained experimentally by means of a damper model, tested on an air pulsating installation.

It follows from the principle of operation of the proposed damper that its frequency characteristic should in theory have an infinite number of minima which is partly shown in Fig. 2.

The damper with the additional pipe has a considerably smaller inertia (time constant) than the normal damping devices, which provide the same degree of pulsation suppression at the transducer's resonant frequency. The experimental amplitude – frequency characteristic of the damper with the additional pipe and its theoretical characteristic plotted from the transfer constant $S = 1/(a + j\omega\tau)$ of a normal plastic damper are shown in Fig. 3. It

will be seen from the curves in Fig. 3 that the time constant of the first damper is $\tau_1$ = 0.0053 sec and of the second $\tau_2$ = 0.02 sec.

In fact $\tau_2$ will be considerably larger, since in the experimental frequency characteristic of the damper the minimum of the characteristic is considerably higher than the actual value owing to the errors connected with the complex nature of the experiment and presence of the second, third and other harmonics in the pulsating pressure.

A possible version of the damper design is shown in Fig. 4.

## SUMMARY

The above damper provides an almost complete suppression of pulsations at the resonant frequency of the manometer transducer; moreover the time constant of the manometer transducer increases only a little (~ $\frac{1}{4}-\frac{1}{6}$ that of the known damping devices).

# A METHOD OF INVESTIGATING THE FLOW STRUCTURE OF AN AIR-WATER MIXTURE IN VERTICAL PIPES

E. M. Novokhatskii

Translated from Izmeritel'naya Tekhnika, No. 6, pp. 22-25, June, 1960

The proposed method of determining the air content in an air-water mixture in a vertical pipe is based on a sharp difference between the permittivity of air and water. If the working space of a capacitor whose plates are made of iron is filled with water which contains dissolved salts the equivalent circuit of the capacitor will have the form shown in Fig. 1.

If small particles of a substance which does not conduct electricity are added to the electrolyte which fills the working space, the change in the values of $C_x$ and $r_x$ will indicate the amount of this substance present in the field of the capacitor.

In order to measure the values of $C_x$ and $r_x$ the circuit shown in Fig. 2 was used.

Current $I_1$ which flows through the circuit under investigation was measured by means of a vacuum contactless thermocouple.

From the value of the current $I_1$ and the voltage U it is possible to calculate the over-all impedance $Z_1$ of the complex circuit:

$$Z_1 = \frac{U}{I_1}.$$

Points a and b in the circuit can be either shorted or a known capacity $C_k$ can be connected to them. In this instance the impedance $Z_2$ of the circuit can also be calculated:

$$Z_2 = \frac{U'}{I_2}.$$

In the formulas for determining $Z_1$ and $Z_2$ by means of U' and U the voltages applied to the electrical circuit under investigation are shown for the case when a known capacitance $C_k$ had been connected to the circuit and when it is lacking, and $I_2$ and $I_1$ are the currents when capacitance $C_k$ is connected and disconnected.

Introducing the notations:

$\omega_1$ is the angular velocity, $\sec^{-1}$, $r_x$ is the resistance of the electrolyte which shunts the capacitance $C_x$, ohms, $C_x$ is the required capacitance, $X_1$ is the total reactance of the series capacitance C and inductance L; $X_1 = \omega_1 L - 1/\omega_1 C$, $a_1$ is the reactance of capacitance $C_k$ and $\omega_1$, ohms,

$$A_1 = \frac{r_x}{1+\omega_1^2 r_x^2 C_x^2};\quad B_1 = X_1 - \omega_1 r_x C_x A_1,$$

we shall obtain for the squares of the impedances

$$Z_1^2 = A_1^2 + B_1^2 .$$
$$Z_2^2 = A_1^2 + (B_1 - a_1)^2, \tag{1}$$

whence

$$B_1 = \frac{Z_1^2 - Z_2^2}{2a_1} + \frac{a_1}{2}. \tag{2}$$

From these equations we find

$$C_x = \frac{1}{\omega_1 r_x}\sqrt{\frac{r_x - A_1}{A_1}}. \tag{3}$$

In the above expression there are two unknown: $r_x$ and $C_x$. If we assume that the values of $r_x$ and $C_x$ do not depend on the frequency of the current and if we carry out the same measurements of the values of $Z_1$ and $Z_2$ at frequency $\omega_2$ we shall obtain an expression for $C_x$ similar to the one in (3):

$$C_x = \frac{1}{\omega_2 r_x}\sqrt{\frac{r_x - A_2}{A_2}}. \tag{4}$$

The value of $A_2$ is calculated from a formula similar to the one derived previously for frequency $\omega_1$. From (3) and (4) we have

$$r_x = \frac{A_1 A_2 (\omega_2^2 - \omega_1^2)}{\omega_2^2 A_2 - \omega_1^2 A_1}, \tag{5}$$

and it is not difficult to find from (3) and (5) the value of $C_x$:

$$C_x = \frac{\sqrt{\left(A_1 - \frac{\omega_2^2}{\omega_1^2} A_2\right)(A_2 - A_1)}}{\omega_1 A_1 A_2 \left(1 - \frac{\omega_2^2}{\omega_1^2}\right)}.$$

On the basis of the results of the first series of experiments frequencies $f_1 = 5$ Mc and $f_2 = 4$ Mc were adopted as the working frequencies. A special high frequency oscillator was constructed accordingly with two fixed frequencies of 4 and 5 Mc.

At these frequencies the formulas for determining $C_x$ take the form

$$C_x = \frac{\sqrt{(A_1-0.64A_2)(A_2-A_1)}}{11.3\cdot 10^6 A_1 A_2}.$$

The values of the reactances $X_1$ and $X_2$ can be found from expressions for $B_1$ and $B_2$:

$$X_1 = B_1 + \sqrt{A_1(r_x - A_1)};\quad X_2 = B_2 + \sqrt{A_2(r_x - A_2)},$$

and the values of C and L from the following expressions:

$$C = \frac{\omega_2^2 - \omega_1^2}{\omega_1\omega_2(X_2\omega_1 - X_1\omega_2)}$$

$$L = \frac{X_1}{\omega_1} + \frac{1}{\omega_1^2 C}.$$

It was impossible to establish a relation between $r_x$ and the volume of the dielectric which fills the working space, since the resistance of the dielectric greatly depends on temperature, and the quantity and type of dissolved salts.

By analyzing the variations of capacitance $C_x$ with the volume of ebonite inserted into its field, it has been established that the permittivity of the mixture of water and ebonite follows with a sufficient degree of accuracy the mixture formula,if the water contains a normal amount of salts in solution:

$$\varepsilon = \frac{\varepsilon' V' + \varepsilon'' V''}{V' + V''} = \frac{\varepsilon' V' + \varepsilon'' V''}{V}, \tag{6}$$

where $\epsilon$ is the permittivity of the mixture, $\epsilon'$ is the permittivity of water, $\epsilon''$ is the permittivity of the second phase (ebonite or air), V' is the volume of water in the working space of the capacitor, V" is the volume of the ebonite or air in the field of the capacitor, and V is the working volume of the capacitor.

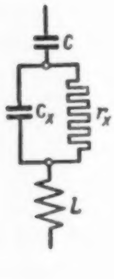


Fig. 1. C) The capacitance of the double layer of charges on the boundary of the electrode and the solution; $C_x$) the capacitance of the capacitor due to its geometrical dimensions and the presence of volume changes in the field; $r_x$) resistance due to the conductivity of the solution; L) inductance due to the presence of iron in the electrical circuit.

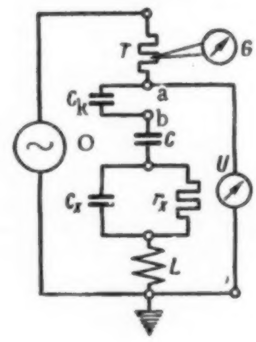


Fig. 2. O) High frequency oscillator; C, $C_x$, $r_x$ and L) the parameters of the circuit under test; $C_k$) the known capacitance; U) a tube voltmeter; T) a vacuum thermocouple; G) a mirror galvanometer type GZP-49.

The working volume of the capacitor was found from the formula

$$V=\frac{\pi}{4}(d_0^2-d^2)\,l,$$

where $d_0$ is the internal diameter of the pipe, cm, $\underline{d}$ is the external diameter of the ring, cm, $l$ is the referred length of the capacitor, cm.

The referred length of the capacitor is in fact a nominal length found from the formula for the capacitance formed by two coaxial cylinders without discounting the end effects. The referred length is always larger than the geometrical length owing to the end effects on the presence of volume charges (ions) in the water.

In calculating the referred length of the capacitor the permittivity of water was taken to be 81.

The volume V" of the ebonite in the field of the capacitor was calculated from the formula

$$V''=n\frac{\pi}{4}d_e^2 l, \tag{7}$$

when $\underline{n}$ is the number of ebonite stems introduced into the field of the capacitor, $d_e$ is the diameter of the ebonite stems, $l$ is the referred length of the capacitor.

In the experiments the permittivity $\epsilon$ of the mixture was calculated from

$$\varepsilon=\frac{1.8C_x\ln\frac{d_0}{d_1}}{l}.$$

The permittivity of ebonite was taken as 3.5. The difference between the permittivities of the mixture obtained experimentally and calculated (6) did not exceed 1.5%.

As the result of these tests it became clear that the value of $r_x$ does not depend on the distribution of the ebonite stems in the field of the capacitor and the value of C varies within the limits of the accuracy of measurements.

The cylindrical electrode placed along the axis of the vertical pipe, with the air and water mixture moving along it, forms a cylindrical capacitor with the pipe whose capacity can be measured by the method outlined above. From the capacitance formula of the cylindrical capacitor it is possible to calculate the permittivity of the air and water mixture and its air content from the mixture equation.

The latter result holds providing that the air phase is distributed quite uniformly over the entire volume of the capacitor. In actual fact the air is not uniformly distributed over the cross section of the pipe and the error obtained in calculating the mean content of air in the mixture will be the greater, the less uniform is the distribution of the air flow in the mixture. This error can be decreased if the flow of the two-phase liquid is divided into several concentric layers, and the air content of each layer is found separately, since the relative non-uniformity of the distribution of air in each layer will be considerably smaller than in the whole of the pipe, and in addition the capacitor formed by the cylindrical layer of the mixture with a decreasing thickness of the layer will approach the characteristics of a flat capacitor, whose capacity is not affected by the distribution of the air in the working volume.

In view of the above considerations, 5 cylindrical electrodes were placed in the measuring section of the pipe. The external diameters of the ring electrodes were selected so as to divide the cross section of the pipe into 5 equal areas, thus making the layers of the liquid, in the zone of an intensive change in the air content, so small within the boundaries between two adjacent rings that the distribution of the air in the volume of the capacitor no longer affected its capacity. The height of the electrode rings was selected in such a manner that the capacities of all the 5 capacitors were about the same. The rings were made streamlined in order to affect as little as possible the flow of the two-phase liquid.

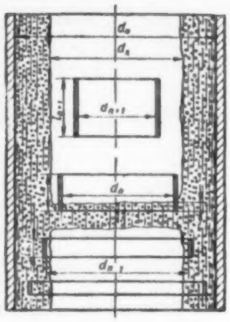

Fig. 3. $d_0$) The internal diameters of the pipe, $d_n$) the diameter of the first pulsating ring counting from the periphery, $d_{n+1}$) and $d_{n-1}$) diameters of rings adjacent to the first pulsating ring, $d_x$) the diameter of the instrument, $l_n$) the referred length of the first pulsating ring, $l_{n+1}$) and $l_{n-1}$) the referred length of the rings adjacent to the first pulsating ring, $l_x$) the relative length of the web between shells.

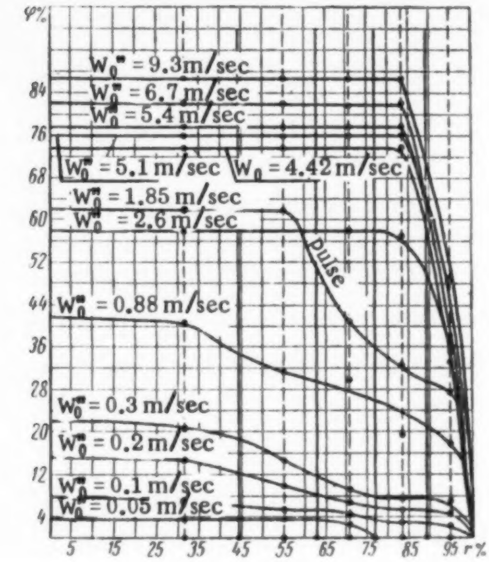


Fig. 4.

The permittivity of the two-phase flow of liquid in its emulsion state was calculated from formulas for multilayer capacitors.

The air content of the mixture between two adjacent rings was found from the formula

$$\varphi = \frac{V''}{V} = \frac{f''}{f} = \frac{\varepsilon' - \varepsilon}{\varepsilon - \varepsilon''}.$$

The latter formula was obtained from (6) and the equality

$$V'' + V' = V.$$

Where $f''$ is the part of the ring area occupied by air between two adjacent electrodes, $f$ is the area bounded by two adjacent ring electrodes.

The mean air content over the whole of the pipe was calculated as the arithmetic mean of the air content of the five layers.

The existence of the shell-type movement of liquid was discovered by the pulsation of the capacitative current. Tests have shown that the shell-type movement of the liquid is established gradually with an increase in the amount of air and a constant flow of water. With a further increase in the amount of air the volume of the shells increases due to their increased length.

In calculating the distribution of the air in the cross section of the pipe during the pulsating movement of the two-phase liquid the model shown in Fig. 3 was assumed. In the pulsating condition one or several ring electrodes are periodically either in the zone of the shell or the web between shells. If the process is averaged with respect to time it can be considered that the ring is in a pulsating condition, a "pulsating ring," and is occupied along its height partly by the web and partly by the shell.

The diameter of the ring will be

$$\ln d_x = \frac{\varepsilon}{\varepsilon - 1}\left[\frac{(l_n - l_x)\,a}{1.8C_n a - l_x} - f + \ln \frac{d_n}{d_0^{\frac{1}{\varepsilon}}}\right].$$

Here

$$f=\frac{1}{\varepsilon_m}\ln\frac{d_0}{d_{n-1}};\quad a=f+\frac{1}{\varepsilon}\ln\frac{d_{n-1}}{d_n};$$

$$b=f+\frac{1}{\varepsilon}\ln\frac{d_n}{d_{n+1}};\quad g=\ln\frac{d_{n+1}}{d_n};$$

and $\epsilon_m$ is the mean permittivity of the mixture calculated from formula

$$\varepsilon_m=\frac{1.8\,C_{n-1}\ln\frac{d_0}{d_{n-1}}}{l_{n-1}}.$$

The air in the working volume of the capacitor is contained in the water web, the ringed layer.and the shell. Having found the sum of these volumes it is not difficult to calculate the air content of the mixture.

The flow of the air and water supplied to the mixer which was 2.5 m away from the measuring portion of the pipe was measured by means of diaphragms.

The variations of the air content along the cross section of an internal diameter of 52 mm, with a referred speed of water flow of $W'_0$ = 1 m/sec, is shown in Fig. 4, where the distances from the center of the pipe (in percent) are plotted along the X-axis and the air content of the mixture (in percent) along the Y-axis; the referred air speed $W''_0$ was taken as a parameter (the referred speed of air or water is taken to be the speed at which each phase would travel if it occupied the entire pipe).

The relative speed of the air $W_r$ is equal to

$$W_r=W''-W'=\frac{W''_0}{\varphi}-\frac{W'_0}{1-\varphi},$$

where $W''$ and $W'$ are the absolute speeds of the gaseous and the liquid phases, $\varphi$ is the mean air content along the cross section of the pipe.

The tests carried out by us have established that the mean relative speeds of air along the cross section of the pipe taken as functions of $W''_0$ for $W'_0$ = 1 m/sec and for three diameters of pipes (69, 52,and 24 mm) agree well with the experimental data of other authors.

Figure 4 shows that for small referred speeds of air, the bubbles concentrate in the center of the pipe, occupying about 80% of the cross section; the water moves near the walls of the pipe.

As the speed of air supply is raised the bubbles penetrate more intensely the boundary layer of water, nevertheless, in all cases the cores of the flow is saturated with air to a greater extent than the periphery, which is confirmed by theoretical considerations [1]. With a rising $W''_0$ the core of the flow becomes increasingly saturated with air and for $W''_0/W'_0$ equal to about 2, pulsations start in the middle of the pipe. A stable shell-type condition of movement begins at $W''_0/W'_0$ equal to about 2.5.

## SUMMARY

1. Despite the tedious adjustment of the high frequency circuit and the relatively complex calculations involved, the present work confirms the advisability of using the new method of investigating the structure of the flow of an air and water mixture in vertical pipes, based on the sharp difference between the permittivities of water and air.

2. The proposed method of investigation is more accurate than other methods; it provides not only mean values of air content in the mixture with respect to the height, and the cross section of the pipe, but also data on the distribution of the air along the cross section of the pipe.

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# THERMOTECHNICAL MEASUREMENTS

## NEW THERMODYNAMIC TEMPERATURE MEASUREMENTS OF SOLIDIFYING GOLD AND ZINC

I. I. Kirenkov

Translated from Izmeritel'naya Tekhnika, No. 6, p. 26, June, 1960

A new gas thermometer and a series of thermostatic devices have been installed at the D. I. Mendeleev All-Union Scientific Research Institute of Metrology for an accurate determination of the thermodynamic temperature scale.

The gas thermometer uses a specially developed dividing chamber which consists of a zero diaphragm manometer whose error does not exceed $\pm 1\ \mu$ Hg. The use of a dividing chamber provides the gas thermometer with several advantages, the main one being the protection of the working gas from pollution by mercury and conditions leading to an increased accuracy of the basic manometer of the gas thermometer. The gas thermometer uses quartz containers filled with pure nitrogen.

A mercury manometer with a capacitative determination of the mercury level was developed for the gas thermometer.

The manometer is supplied with two capacitative heads, one stationary in the lower leg and the other, adjustable in the upper leg of the manometer. The constancy of the mercury in the heads is checked with great precision by means of electrical capacity measurements, between the mercury surface and the flat steel electrodes fixed to the heads. The diameter of the mercury surface in the head is equal to 80 mm. The mercury capacitor is included in the arm of an ac bridge (of 1000 cps) whose remaining theee arms are constant. The bridge is balanced at a strictly defined position of the mercury level in the head.

The reading of the manometer indication is carried out by means of a microscope which is connected to the upper moving head and sighted against a fixed scale. The manometer measures pressure with an error of the order of $\pm 1$-$3\ \mu$ Hg.

Temperatures of the triple water point, the balance point between solid and liquid zinc and solid and liquid gold were measured by means of the new gas thermometer. The measurements provided an evaluation of the last two reference points in terms of the thermodynamic scale.

Measurements of the triple water point temperature were carried out in the usual manner but with a container of a larger size. The zinc point was measured by means of a vertical three-winding oven, and the container of the gas thermometer was lowered into the crucible with zinc, which contained some 0.0003% of impurities. The measurements at the gold point were carried out by comparing the gas thermometer with thermocouples which were previously calibrated at the temperature of the hardening of gold. The comparisons were carried out in a vertical three-winding oven with a mass of vigorously stirred liquid tin which was heated up to the required temperature.

As the result of these measurements the following values in the thermodynamic scale were obtained:

$$t(Zn) = 419.57 \pm 0.02°C,$$

$$t(Au) = 1064.4 \pm 0.2°C.$$

A detailed description of the equipment and methods of measurement will shortly be published in the proceedings of the VNIIM.

# AN AUTOMATIC PHOTOELECTRIC COLOR PYROMETER TsÉP-3

D. Ya. Svet

Translated from Izmeritel'naya Tekhnika, No. 6, pp. 26-30, June, 1960

The advantages of the objective method of color bichromatic pyrometry for controlling temperatures as compared with methods based on brightness or partial or total radiation are well known both from research and industrial experience. In the Soviet Union and later abroad commercial automatic color pyrometers were produced.

As the result of extensive investigations and experience gained in the use of color pyrometers type TsÉP-2M, which were described in sufficient detail in [1], it became possible to construct a more perfect instrument TsÉP-3* which despite several improvements is simpler than TsÉP-2M both in production and use.

TsÉP-3 is constructed according to the same circuit as TsÉP-2M based on the use of a radio-electronic computing device for measuring the logarithm of the spectral ("blue-red") ratio, which bears, according to Wien's law, a linear relation to the reciprocal value of color temperature.

The TsÉP-3 consists of three units: the transducer (CPT), the electronic unit (EU) and an indicating instrument type ÉPP-09 with a speed of operation of 1-3 sec and more, or another normal millivoltmeter. The transducer is placed in a water cooled body of a rectangular shape which also contains the basic optical system with a sighting device, a thermostatic unit with a photoelectric cell and preamplifier, a device for a hand and automatic control of the brightness level, an indicator and control elements. In order to remove dust and smoke from the field of vision of the instrument a system of blowing compressed air or inert gas, from a hose to a special hood placed over the tube of the transducer objective is used.

The optical system of the TsÉP-3 set, comprising a standard objective Yupiter-3 (Jupiter-3), a microcollector and a light channel provides a completely "floodlit" cathode of the photocell under any value of the aperture. The latter, unlike all the pyrometers described in the technical literature, can be varied in the TsÉP-3 set in the range of 1/5 to 1/160 during measurement or adjustment by simply turning a knob on the CPT unit (see below). The TsÉP-3 set is calibrated by using an exchangeable collimator lenses which makes it possible to use as a radiating surface the middle of an incandescent filament of an area of 1 $mm^2$.

The sighting device of the TsÉP-3 set makes it possible to see during measurements not only the space immediately in front of the objective, but also that part of the radiating surface which illuminates the photocell cathode for a given aperture (angle of vision). With such a sight it becomes easy to determine, the temperature gradients on the radiating surface, to direct the pyrometer onto the required section of the surface, etc.

Current pulses, proportional to two spectral intensities, are produced at the output of a vacuum photocell F-8 by means of an obturator disk which has appropriate light filters and is driven by a synchronous motor. In order to stabilize the spectral characteristic the photocell is placed in an automatically controlled thermostat.

Since the levels of spectral intensities change with temperature more rapidly than their ratios, an automatic gain control by means of a thermistor is used in the electronic unit (EU) of this set, just as it was done in

* TsÉP-3 has passed its state tests and has been recommended for mass production. The instrument has been developed by Chief Designer P. A. Efimov with the participation of E. S. Lipin, L. V. Vengerskii, P. G. Lebchuk **, P. A. Shurgaev, and V. I. Kurochkina on the basis of the proposed circuit and investigations carried by the author of the present article.

** Deceased.

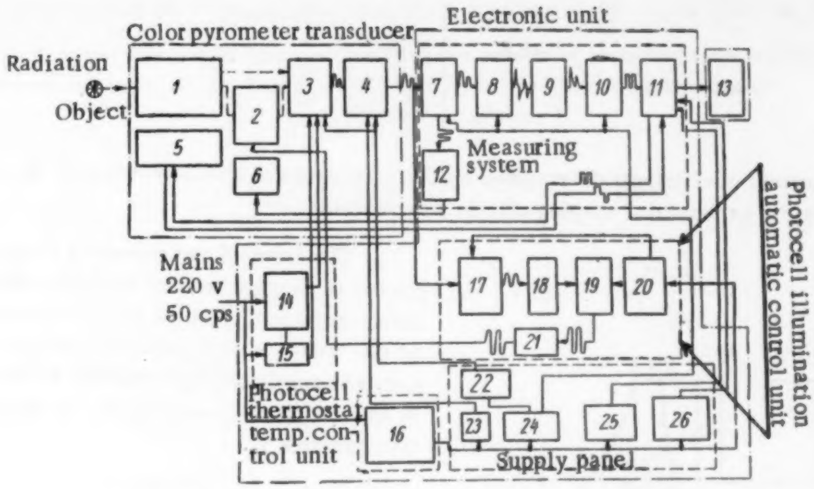


Fig. 1. 1) Optical system: obturator and mechanism for controlling the angle of vision; 2) actuating mechanism for brightness control; 3) photocell with thermostat; 4) pulse preamplifier; 5) commutator for synchronous switching; 6) brightness level indicator; 7) pulse amplifier; 8) differential amplifier with level stabilization; 9) pulse detector with an exponential shaping circuit; 10) voltage limiter; 11) output stage of the voltage limiter with a filter (RC); 12) brightness indicator amplifer; 13) an indicating and recording instrument; 14) controlled heater rectifier; 15) source of negative biasing; 16) ferroresonating voltage stabilizer ON-250; 17) separating stage of the amplifier; 18) pulse rectifier; 19) comparison modulating stage; 20) source of supplies and reference voltage; 21) output stage of the brightness amplifier; 22) parametric voltage stabilizer; 23) source of the tube heater supplies; 24) source of the measuring system and transducer supplies; 25) stable voltage source for the output stage voltage limiter; 26) negative bias supply for the output stage voltage limiter.

the TsÉP-2M instrument. However, when high temperatures are controlled automatically for a long time, variations of the brightness level, i.e., of the intensity of radiation incident to the pyrometer objective, can greatly exceed the permissible limits.

In the TsÉP-3 as in the TsÉP-2M instrument these limits are indicated by a special pointer instrument mounted on the transducer control panel. In order to prevent excessive variations of the radiated flux intensity incident to the photocell cathode, the TsÉP-3 instrument is supplied with an automatic brightness control consisting of a compact servo system. This system controls a special device for nonselective absorption of radiation If required, the automatic brightness control system can be switched off or altogether omitted from the set. For this purpose an alternate manually operated brightness control is provided by means of a knob on the transducer control panel.

The functional circuit of the instrument is shown in Fig. 1. The electronic unit, which is connected to the transducer by means of a cable, contains, in addition to the basic measuring system and the source of supplies, several auxiliary units.

The measuring channel consists of an amplifier with an automatic gain control and a pulse logarithmic ratio meter for measuring ratio $\rho$ of two spectral intensities $b_1$ and $b_2$ (with effective wavelengths $\lambda_1$ and $\lambda_2$).

These intensities are measured by the difference in the duration of $\tau_1$ and $\tau_2$ which are limited at the $U_0$ level of exponential pulses formed at the output of the pulse detector, when its input is fed by pulse voltages $U_1$ and $U_2$, which are proportional to the spectral intensities:

$$U_1 = \xi_1 b_1 \qquad U_0 = U_1 e^{-\frac{\tau_1}{\alpha}}$$
$$U_2 = \xi_2 b_2 \qquad U_0 = U_2 e^{-\frac{\tau_2}{\alpha}}, \tag{1}$$

where $\xi_1$ and $\xi_2$ are constant coefficients determined by the total spectral characteristics of the photocells and light filters in use; $\alpha$ is the exponential shaping circuit time constant.

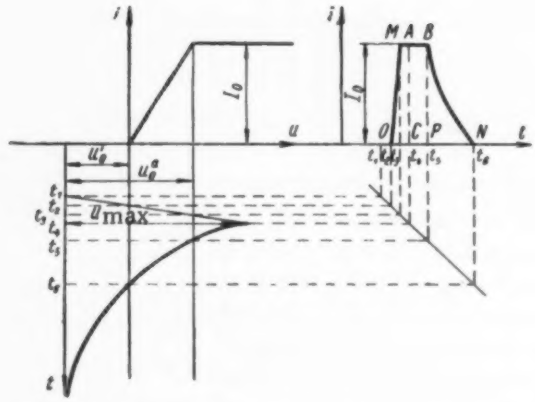


Fig. 2. Amplitude limitation of an exponential pulse.

The input of the recording instrument is fed by means of the synchronous switching device* with a direct voltage $U_=$, which is proportional to the difference of two voltages with pulse durations of $\tau_1$ and $\tau_2$ and a constant amplitude $U_0$. Voltage $U_=$ is a linear function of the reciprocal values of the measured color temperatures $T_c$:

$$U_= = \text{const}\,\alpha^{-1} \ln \frac{U_1}{U_2} = \text{const}\,\alpha^{-1}\left(\ln \frac{b_1}{b_2} + \ln \frac{\xi_1}{\xi_2}\right) \tag{2}$$

or by using Wien's formula [2]:

$$U_= = \text{const}\,\alpha^{-1}\left[\ln \frac{\xi_1 \lambda_1^{-5}}{\xi_2 \lambda_2^{-5}} - \frac{(\lambda_1 - \lambda_2)\, c_2}{\lambda_1 \lambda_2} T_c^{-1}\right]. \tag{3}$$

When this basic expression for the spectral relation in this logarithmic pyrometer was derived,it was assumed that the speed of the exponential pulse rise at the output of the pulse detector was infinite. In practice the duration of the leading edge of exponential pulses,as well as the portion of the current rise in the amplitude limiter, are finite. Thus,a certain error will be made in the process of finding logarithms and ratios, an error which we shall examine by adopting the following notations:

$S = I_0/(U_0'' - U_0')$ — the mutual conductance of the amplitude;
$T = F^{-1}$ — the repetition period of the exponential pulses;
$t_n$ — the duration of the pulse leading edge at the input of the amplitude limiter;
$t_p$ — spacing between adjacent pulses.

$$\tau_i' = t_4 - t_2;\ \tau_i'' = t_6 - t_5;\ \tau_i = \tau_5 - \tau_4;\ \Delta U_0 = U_0'' - U_0'. \tag{4}$$

The above values of the voltages and time intervals are shown on the plane diagram (Fig. 2).

If this transformation process is examined in its time sequence it will be seen that the rectangular pulse CABP corresponds during interval $\tau_i = \alpha \ln \frac{U_{max}}{U_0''}$ to the transformation of an ideal exponential pulse in an amplitude limiter with an infinitely steep edge, i.e., with a rectangular volt-ampere characteristic. The rising portion OMA of the pulse is determined by the leading edge of the input pulse and the steepness of the limiter characteristic

$$\tau_i' = t_n\left(1 - \frac{U_0'}{U_{max}}\right). \tag{5}$$

* A synchronous switch can consist of a miniature commutator, or a vibrating converter VP. Good results are obtained from electronic switching systems using tubes or transistors.

The exponential part BN of the output pulse has a duration of $\tau_1^{*} = \alpha \ln \frac{U_0^{*}}{U_0^{'}}$; i.e., it is independent of the exponential signal amplitude. If, in future, we express the results of transformation as the mean current, we shall obtain the value of the latter at the output of the limiter in the following expression:

$$I_m' = T^{-1} S \left[ (t_3 - t_2) \frac{\Delta U_0}{2} + (t_4 - t_3) \Delta U_0 + \right.$$
$$\left. + \int_{t_4}^{t_5} \left( U_{max} e^{-\frac{t}{\alpha}} - U_0' \right) dt \right] + I_0 T^{-1} \alpha \ln \frac{U_{max}}{U_0^{''}} \tag{6}$$

or after appropriate transformations:

$$I_m = I_0 T^{-1} \left\{ \frac{t_n}{2} \left( \frac{U_0^{''} - U_0^{'}}{U_{max}} \right) + \alpha \ln \frac{U_{max}}{U_0^{''}} + \right.$$
$$\left. + \alpha \left[ 1 - \frac{U_0^{'}}{U_0^{''}} \ln \left( 1 + \frac{U_0^{''}}{U_0^{'}} \right) \right] \right\}. \tag{7}$$

When logarithms are taken, the "useful effect" is determined by the second term of the right hand-side of (7). The third term characterizes the constant error which does not depend on the value of the signal being transformed and depends only on the relative value of the converter parameters. The first term determines the error due to this method of taking logarithms and caused by the finite value $t_n$ of the leading edge of the input exponential pulse, and the "nonideal" operation of the amplitude limiter characterized by the value of $U_0^{''} - U_0^{'}$.

The logarithm of the ratio of amplitudes $U_{m1}$ and $U_{m2}$ of two exponential pulses is measured by means of the mean output limiter current, which is determined by the difference in the duration of pulses at the output of (7). Thus in the long run the following quantity is measured:

$$I_m = I_0 T^{-1} \left[ \frac{t_n \Delta U_0 (U_{m1} - U_{m2})}{2 U_{m1} U_{m2}} + \alpha \ln \frac{U_{m1}}{U_{m2}} \right]. \tag{8}$$

i.e., in obtaining the ratios, as one would expect, the constant error made in taking the logarithm is completely excluded.

The effect of the converter parameters $U_0^{'}$ and $U_0^{''}$* is exercised only through the value of $t_n$.

Having expressed the relative logarithmic error by $\delta$:

$$\delta = \frac{t_n (U_0^{''} - U_0^{'}) (U_{m2} - U_{m1})}{2 U_{m1} U_{m2} \alpha (\ln U_{m1} - \ln U_{m2})},$$

and denoting by $D = U_{m2}/U_{m1}$ the dynamic range of the voltage ratios, and by $n = U_{m1}/U_0^{''}$ the coefficient of the amplitude limitation, we shall obtain the following expression for the relative error:

$$\delta = \frac{t_n (D-1)}{2n \alpha \ln D^D}. \tag{9}$$

*It is assumed here and henceforth that $U_0^{'}$ and $U_0^{''}$ remain constant for the time T of the duration of the two pulses.

For the particular case of a wide dynamic range $D \gg 1$, expression (9) can be simplified and it takes the form:

$$\delta = \frac{t_n}{2n\alpha \ln D}, \tag{10}$$

From the above expression it obviously follows that the error decreases with a rise in the exponential time constant $\alpha$. In practice the time interval $t_n$ between the pulses whose logarithms are being taken limits the rise in $\alpha$.

The maximum permissible value of $\alpha_{max}$ for this method of transformation can be determined from the inequality

$$\begin{gathered} U_{max}\, e^{-\frac{t_p}{\alpha_{max}}} < U_0', \text{ for } U_{max} = DU_{min} \\ \alpha_{max} = \frac{t_p}{\ln \frac{DU_{min}}{U_0'}}. \end{gathered} \tag{11}$$

In fact, however, $\alpha_{max}$ is always smaller than this value. In calculations this can be accounted for by increasing the value of $U_{min}$, i.e., by taking in (11) the value of $U_{min}' = bU_{min}$ instead of $U_{min}$, where $b > 1$ is a certain coefficient, which accounts for the possible instability of the voltage (due to drift, etc.).

By substituting the value of $\alpha_{max}$ from (11) into (9), and introducing the notation $\vartheta = t_n/t_p$ we shall obtain, after simple transformations, an expression for determining the error:

$$\delta = \frac{\vartheta (D-1) \ln nD}{2nD \ln D}. \tag{12}$$

The error of the TsEP-3 set as calculated from (12) for the maximum value of temperature, i.e., $D = D_{max}$, is considerably smaller than the tolerance.

It should also be noted that in set TsÉP-3, the same as in all the single channel color pyrometers [2] which measure ratios, the variations of the level of the voltages whose ratio is being measured, is neglected. Providing the speed of these variations is such that during one period T of the obturator rotation the above parameters can be considered constant, the effect of the transfer constant of the channel including the pulse detector is also neglected.

The "loss" of the direct component due to the ac amplification of the currents involved in the measurement of ratios does not affect anything, which is natural, since the dc component is eliminated in a linear circuit and the ratio can only be affected if there exist nonlinear distortions.

However, the identity of the amplitudes at the input and the output of the channel will then be obviously lacking.

In fact, let us denote the ratio of amplitudes $U_1$ and $U_2$ of unipolar, positive pulses, for instance, by $\rho$. Let the instantaneous values of these pulses spaced in time be represented, respectively, by amplitude normalized functions of time $\Phi_1(t)$ and $\Phi_2(t)$. Then the dc component of a pair of pulses with a period of $T = 1/n$, where $\underline{n}$ is the number of rotations of the obturator per second, can be written in the form:

$$\begin{gathered} U_n = \frac{1}{T}\left[ U_{1m} \int_0^{\tau_1} \Phi_1(t)\, dt + U_{2m} \int_0^{\tau_2} \Phi_2(t)\, dt \right] = \\ = \beta_1 U_{1m} + \beta_2 U_{2m}, \end{gathered} \tag{13}$$

where $\beta_1$ and $\beta_2$ are constant for the given shape and duty ratio of pulses.

Hence by denoting the ratio of the pulse amplitudes after the exclusion of the dc component $U_n$ by $\rho'$ we obtain:

$$\rho' = \frac{U_1 - U_n}{U_2 - U_n} = \frac{1-\beta_1-\beta_2\rho^{-1}}{1-\beta_2-\beta_1\rho}. \tag{14}$$

In set TsÉP-3 the "identity" of the ratio at the input and the output of the channel is preserved owing to the use in front of the detector of a differentiating circuit which fixes the zero level (thus making $U_n = 0$), i.e., linear relations in the readings of the indicating TsÉP-3 instrument are ensured in practice with an error determined from (12).

Basic theoretical characteristics of TsÉP-3. The range of measurement and recording of color temperatures is 1400-2800°C; the number of bands is 3-5; the range of separate bands amounts to 200-400°C* (the overlapping of the scales amounts to at least 20°); the sensitivity is not less than ±0.25% of the maximum value in any given band.

The basic error of measurement does not exceed ±1% of the maximum value of any band if it is determined by means of the radiating surfaces of standard incandescent lamps.

The complete TsÉP-3 set includes, in addition to the two basic units and a standard recording instrument and connecting cables with plugs, also a calibrating device with a collimator which makes it possible to calibrate the instrument by means of a set of standard incandescent lamps, a rheostat for their precise setting, a universal stand, etc.

Since, in the TsÉP-3 instrument the speed of measuring the color temperature is determined by the period of the obturator rotation, it is possible to use with it, as a recording instrument for research purposes, a loop or cathode ray oscilloscope capable of registering color temperature in 0.04 sec.

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# PRELIMINARY SELECTION OF INSTRUMENTS FOR AUTOMATIC CONTROL AND CHECKING


N. F. Broido



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A correct selection of instruments for measuring and controlling parameters of technological processes involves the evaluation of the technological properties of the object under control and the determination of the static and dynamic characteristics of the objects and the instruments. Hence, the preliminary selection of controlling instruments from the point of view of their dynamic characteristics should be carried out tentatively on the basis of the relation of the object's dead time $\tau_0$ to its time constant $T_0$. This relation characterizes the dynamic properties of the object. Table 1 shows the values of this ratio and the corresponding type of regulator to be recommended [1].

*By means of the switch in the CPT the range of measurement can cover ~1000°C (without changing the obturator disk).

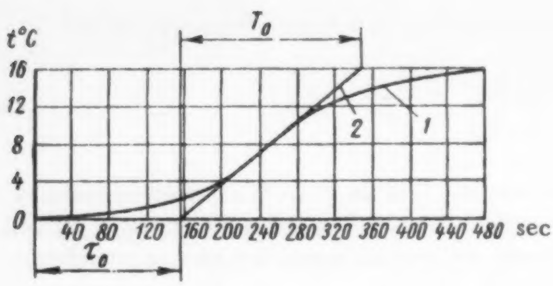


Fig. 1. 1) Response curve; 2) tangent to the response curve.

TABLE 1

| Type of regulator | $\tau_0/T_0$ |
|---|---|
| Relay regulators | Less than 0.5 |
| Continuous regulators | From 0.5 to 1 |
| Pulse regulators | Over 1 |

The value of $\tau_0/T_0$ is determined from the response curve which is obtained either by calculation or experimentally for an intermittent operation of the object [2].

For the illustration of the method of obtaining the ratio $\tau_0/T_0$. Fig. 1 shows the response curve of the upper, radiation portion of a direct-flow boiler [3], from which we obtain the ratio $\tau_0/T_0$ approximately equal to 0.81 which according to Table 1 requires the use of a continuous regulator.

The preliminary choice of an instrument will be considerably more valuable if its dynamic characteristics are known. They are characterized by the instrument's time constant $T_i$ and its dead time $\tau_i$, which depend both on the design of the instrument and the condition of work of the object.

If the ratio $\tau_i/T_i$ increases for any type of instrument it means that it is beginning to react slower to variations in the technological process. This may worsen the measurement or control of the corresponding parameter, since during time $\tau_i$ this parameter may deviate by an unallowable amount from the set value.

When the measured parameter changes intermittently, the values of $\tau_i$ and $T_i$ are obtained from the response curve of the instrument. It is desirable that the laboratory conditions in obtaining the response curve should be as near as possible to the working conditions. If they differ considerably the test results will only have a comparative value unrelated to the controlled object. It is obvious that the preliminary laboratory testing of the instrument is less accurate than its testing directly with the controlled object.

Figure 2 shows an experimentally obtained response curve of a thermocouple type TKhK-XIII, connected to a millivoltmeter grade 0.5. From this curve, which is practically exponential, we find $\tau_i$ = 16 sec and $T_i$ = 118 sec. Similar curves can be obtained for other instruments as well [4]; thus the similarity of the dynamic properties of the objects and the instruments is established.

It was stated above that parameters $T_i$ and $\tau_i$ depend on the conditions of operation of the object. Let us demonstrate it for instruments measuring the temperature of media. In this instance, the effect of the medium on the instrument characteristics is determined by the heat transfer coefficient $\alpha$.

Figure 3 shows an experimental curve 1 for a glass thermometer with a scale of 0-500°C (GOST 2823-59), produced by the author, which expresses the relation $T_i = f(\alpha)$ and curve 2 calculated by G. M. Kondrat'ev's method [5]. Similar curves have also been obtained by other experimenters [6].

Coefficient $\alpha$ depends on the condition of operation and loading of the object ($Q_0$). It is difficult to express this relation for all cases in a general manner, therefore we shall limit ourselves to examining a particular case in which the transducer of the instrument (for instance a thermocouple) is mounted in a pipe through which a liquid is flowing.

If the loading of the object is changed suddenly by $\Delta Q_0$, it is possible to consider approximately that the speed of flow of the liquid also changes suddenly by $\Delta W$, and the coefficient $\alpha$ by $\Delta\alpha$.

From the response curve for this instrument we find the value of $T_i$. Coefficient $\alpha$ is determined from the formula

$$\alpha = \frac{N_u \lambda}{d_1}, \qquad (1)$$

where $N_\mu$ is Nusselt's number $\lambda$ is the thermal conductivity of the liquid, $d_1$ is the diameter of the transducer.

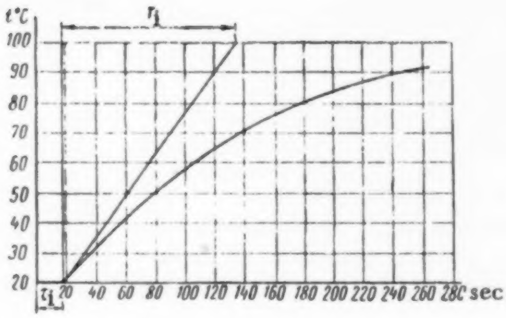


Fig. 2.

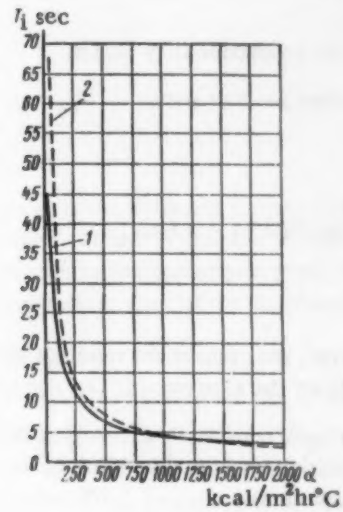


Fig. 3.

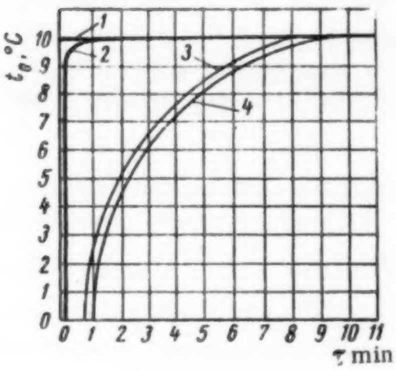


Fig. 4. 1) Final changes of temperature; 2) thermocouple response curve taken without a protecting jacket by means of ÉPD-37; 3) the same, but in a jacket filled with transformer oil; 4) the same, but in a cover without the oil.

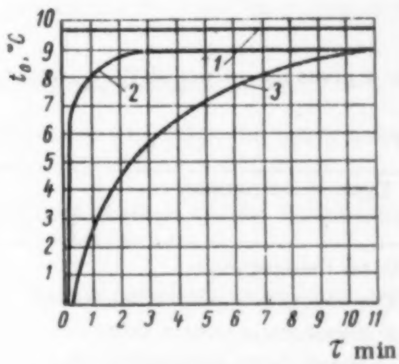


Fig. 5. 1) Final change of temperature; 2) response curve of regulator 04-TG-610 with a thermal cylinder but without a protective jacket; 3) the same, with a protective jacket.

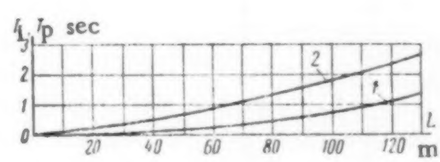


Fig. 6.

On the other hand, Nusselt's number is equal to [7]:

$$N_u = 0.023\left(\frac{d_2}{d_1}\right)^{0.45} \mathrm{Re}^{0.8}\,\mathrm{Pr}^{0.4}, \tag{2}$$

where $d_2$ is the diameter of the pipe, Pr is the Prandtl criterion, Re is the Reynolds number.

$$\mathrm{Re} = \frac{Wd_2}{\nu}, \tag{3}$$

where $\nu$ is the kinematic viscosity of the liquid.

The relation between the loading and the speed of flow may be represented as

$$W = kQ_o \tag{4}$$

where k is the proportionality factor.

Therefore, we can write

$$\alpha = \varphi(Q_o). \tag{5}$$

or considering that $T_i = f(\alpha)$,

$$T_i = x(Q_o). \tag{6}$$

However, the instrument readings do not always follow an exponential law when $\alpha$ changes intermittently. Deviations from the exponential law are caused by various factors: friction in the kinematic links, inertia, etc.

Under such conditions it is impossible to use the time constant, and it is necessary to use the time required for the establishment of steady readings or the time of the regulator operation $\tau_r$. This time need only be measured with an accuracy of 2-5% below the final value of the measured or controlled parameter [8]. As an example, Fig. 4 shows a nonexponential response curve of an electronic temperature regulator, type ÉPD-37 and Fig. 5 of a pneumatic temperature regulator type 04-TG-610. These curves have been reproduced from [9]. For these cases the following expression will hold:

$$\tau_r = \lambda_1(Q_o). \tag{7}$$

Table 2 gives the values of $T_i$, $\tau_i$, and $\tau_r$ for several instruments.

TABLE 2

| No. | Type of instrument | $T_i$ sec. | $\tau_i$ sec. | $\tau_r$ sec. | $k_i = \frac{\tau_i}{T_i}$ | $k_r = \frac{\tau_i}{\tau_r}$ |
|---|---|---|---|---|---|---|
| 1 | Glass thermometer | 3.75 | 0.2 | 15.5 | 0.053 | 0.013 |
| 2 | The same, in a protecting jacket | 34 | 3.5 | 136 | 0.103 | 0.026 |
| 3 | A manometric stream thermometer (with acetone fillers) | 8.5 | 2.0 | 55 | 0.235 | 0.036 |
| 4 | Thermocouple type TKhK-XIII with a millivoltmeter | 118 | 16 | 440 | 0.135 | 0.036 |
| 5 | Dilatometric thermometer | 11.7 | 1.0 | 32 | 0.085 | 0.031 |
| 6 | Thermocouple without a protective jacket used with a ÉPD-37 instrument | – | 3.0 | 120 | – | 0.025 |
| 7 | The same, in a jacket filled with transformer oil | – | 40.0 | 516 | – | 0.078 |
| 8 | The same, in a jacket without oil | – | 60.0 | 600 | – | 0.1 |
| 9 | A pneumatic temperature regulator type 04-TG-610 with a thermal cylinder but without oil and a protecting jacket | – | 3.0 | 300 | – | 0.01 |
| 10 | The same, with a protecting jacket | – | 20.0 | 660 | – | 0.03 |

Let us now examine similar problems with respect to instruments which receive pulses recording pressure or difference of pressures between two points. Commercially such instruments consist of manometers, differential manometers, pneumatic and hydraulic regulators, etc. These instruments are connected at one end to the pneumatic mains and at the other to the object in the place where the pulse is originated. For the sake of simplicity

let us examine the behavior of the instrument when a sudden pulse is produced in the compressed air pressure. With such a pulse the variation in the reading of the instrument may follow an exponential or another law. In the first instance, the inertia of the system consisting of the pneumatic pipe and the instrument is characterized by its time constant [10]:

$$T_i = \frac{128\mu L}{\pi d^4 (P_b + P_s)}\left(0.785 d^2 L + V + \frac{Fl\,(P_b + P_s)}{P_s}\right). \quad (8)$$

where L is the length of the pneumatic pipe; d is the internal diameter; $\mu$ is the dynamic viscosity of compressed air; $P_b$ is the initial pressure of air in the pneumatic pipe; $P_s$ is the sudden change in pressure in the compressed air; V is the volume of the instrument chamber or the servomotor connected to the pneumatic pipe; F is the effective area of the instrument or servomotor diaphragm; and $l$ is the displacement of the diaphragm.

The exponential curve oscillograms for this case are given in [11].

If we assume that in formula (8) V = 0, F = 0, $l$ = 0, we shall obtain an expression for the time constant $T_p$ for the pipe line only with respect to L. Figure 6 shows curve 1 which represents the relation of $T_p$ to L for the following initial values: $P_b = 10^4$ kg-wt/m², d = 0.00 m, $\mu = 0.184 \cdot 10^{-5}$ kg·sec/m².

Curve 2 is plotted according to the data in (8) taking into consideration the values of V, F and $l$ for a pneumatic mass-produced servomotor type 25s52nzh with a nominal port diameter of 100 mm. Thus in the case of this instrument the conditions of its installation, i.e., the values of L and d affect considerably its dynamic properties.

It should be noted that the variation in the reading of these instruments for a sudden change of pressure do not always follow an exponential law [12].

The data given in Table 2 was obtained for the following conditions of operation:

For instruments Nos. 1-5, the initial temperature of the transducer was 15-20°C, the temperature of the water into which the transducer was immersed was 90-95°C;

For instruments Nos. 6-10, the difference between the temperature of water and the initial temperature of the transducers was 10°C [9].

It will be seen from Table 2 that for each type of instrument there is a definite value of the ratio $k_i = \tau_i/T_i$ or $k_r = \tau_i/\tau_r$ which varies with changes in $T_i$ and $\tau_r$.

Since the characteristic $T_i = f(\alpha)$ follows approximately a hyperbola (Fig. 3) one can expect that $k_i$ and $k_r$ will vary in the same manner with respect to $\alpha$

## SUMMARY

Having plotted for various instruments the curves of $k_i = f_1(\alpha)$ and $k_r = f_2(\alpha)$ for several values of $\alpha$ (from the data of industrial or laboratory tests), it is possible to find $k_i$ and $k_r$ for any other values of $\alpha$. Similarly for pneumatic instruments we have $k_i = f_1(P_s)$ and $k_r = f_2(P_s)$. This facilitates the preliminary choice of instruments without the necessity of taking many response curves. The ratio $\tau_i/T_i$ can also be used for a mathematical analysis of the behavior of automatic control systems [13].

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## A CONTACTLESS REMOTE SYSTEM FOR MEASURING THE PARAMETERS OF HIGH-TENSION CIRCUITS


V. M. Gerashkin and D. V. Karetnikov



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The possibility of measuring safely certain parameters at the high-tension terminal of accelerating tubes, high voltage dc equipment and transmission lines has become an important question. Radiotelemetering methods are now being used for this purpose [1].

Up to voltages of 1 Mv it is advisable to use photoelectric methods. The photoelectric methods described in literature [2-5] are complicated and require specially constructed components.

For this purpose we have developed a single channel contactless telemetering system with time separation of eight transmitted parameters. The system uses a photoelectric method with light modulation by means of lamp TMH-2 and only the most simple pulse circuits consisting of Soviet mass-produced components.

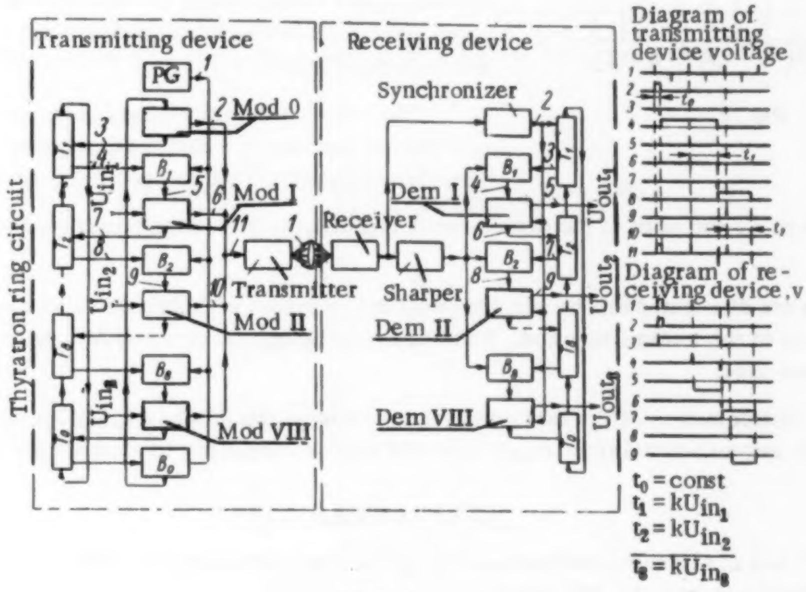


Fig. 1.

This system was used for measuring at a distance eight parameters of an ionic source of a high tension tube. For transmission purposes all the measured parameters were transformed by means of simple transducers into voltages which varied between 0 and +10 v.

Voltages $U_{in1}$, $U_{in2}$, . . . are fed from the output of each transducer (Fig. 1) to the corresponding modulators and are linearly transformed into time intervals $t_u = kU_{in}$. Trigger circuits with one stable position, a cathode coupling and positive grid biasing [6, 7] were used as modulators.

Each modulator is tripped through a corresponding coincidence rectifier $B_0, B_1, \ldots B_8$, by a pulse generator PG which consists of a multivibrator with a positive biasing [6, 7]. For sequential sampling of modulators, the transmitting device is provided with a thyratron-ring circuit [7] in which the switching of each subsequent link is accomplished through a modulator and a coincidence rectifier. The initial position is provided by a simple relay circuit which is not shown in Fig. 1. When thyratron $T_0$ is conducting, the coincidence rectifier $B_0$ is kept open by the thyratron and transmits the first positive pulse from the pulse generator. This pulse triggers the synchronizing modulator Mod 0. The total number of modulators in an eight channel system amounts to 9, determining the choice of a carrier frequency which is a multiple of 9 (963 cps). At the modulator output there appears a constant duration pulse ($t_0 = 30\ \mu$ sec). The trailing edge of this pulse triggers thyratron $T_1$. The voltage drop produced by the current though $T_1$ extinguishes $T_0$ and at the same time prepares $B_1$ for passing the next positive pulse. The second generator pulse through $B_1$ triggers Mod. I which forms a pulse with a duration proportional to the effective input voltage (for $U_{in} = 0$, $t_{u0} = 100\ \mu$ sec). The trailing edge of this pulse triggers the next thyratron $T_2$. At the same time $T_1$ is extinguished and the next modulator Mod. II is prepared for operation, etc. The triggering of the thyratron by the trailing edge of the pulse excludes the possibility of several modulators operating simultaneously.

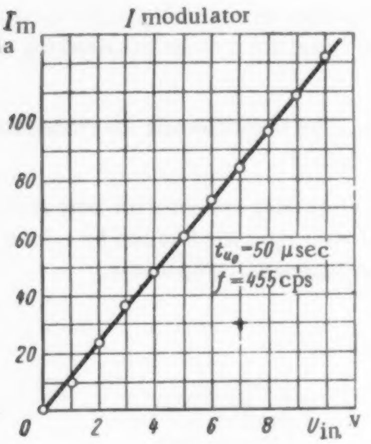


Fig. 2.

At the output of each modulator a positive and a negative indicating pulse are produced ($t = 5\ \mu$sec), whose interval is proportional to the measured quantity. The pulses from all the modulators are fed sequentially to the common input of the transmitting stage.

Remote transmission is done by means of a target tube TMN-2. The use of incomplete modulation makes it possible to raise the transmitted frequency of the TMN-2 tube up to 175 kc. The distance between the tube and the receiving photocell was 1.5-2 m.

At the receiving side the light pulse train was received by means of a photomultiplier FÉU-2. After amplification, the synchronizing pulses are selected by the limiting circuit and used (after each sampling cycle of all the demodulators) for restoring the thyratrons and demodulators to their original condition. The demodulators produce pulses with a duration equal to the interval between the indicating pulses.

The value of the transmitted parameter is registered by means of a pointer instrument which reads the mean value of the current. The current pulses are fed to each instrument at a frequency of 107 cps.

In order to make the work of the demodulators reliable, the indicating pulses are shaped in a Schmitt circuit [8].

The pulses are distributed among the demodulators by means of a thyratron-ring circuit and coincidence rectifiers similarly to the transmitting end. The difference being that at the receiving end both positive and negative pulses are used.

The mean characteristic of the first telemetering channel (Mod I) $I_{out} = f(U_{in})$ is shown in Fig. 2. The error of the whole system was obtained experimentally and was found not to exceed 6% for any channel.

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# AN APPARATUS FOR TESTING THE EFFECT OF EXTERNAL MAGNETIC FIELDS ON INSTRUMENTS

M. Kh. Shliomovich

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A single coil is recommended by existing specifications in the USSR [1] and certain foreign countries (for instance [2, 3]) for the provision of an external magnetic field in testing electrical measuring instruments. Moreover it is stipulated that the instrument has to be placed into an almost homogeneous (before the introduction of the instrument) field in accordance with which the foreign standards state that the diameter of the coil must exceed the dimensions of the instrument at least by a factor of 4. However, in practice, our instrument making plants, scientific research institutes, and other organizations use for a homogeneous external magnetic field double Helmholtz coils [4].

It is known [4] that for a single coil with w turns, a cross section of the winding of 2a × 2b and a mean radius R (Fig. 1) the magnetic field strength component produced along the x-axis by current I, at some point P with coordinates x and y will be

$$H_x = \frac{0.2\pi I w R^2}{\rho^3}\left\{\left[1 - \frac{a^2}{2\rho^4}(R^2 - 4x^2) + \frac{b^2}{6\rho^4 R^2}(2R^4 - 11R^2x^2 + 2x^4)\right] + \right.$$
$$\left. + \frac{3}{4}\frac{y^2}{\rho^4}\left[(R^2 - 4x^2) - \frac{5a^2}{2\rho^4}(R^4 - 12R^2x^2 + 8x^4) - \frac{b^2}{6\rho^4 R^2}(12R^6 + 159R^4x^2 - 136R^2x^4 + 8x^6)\right]\right\}, \quad (1)^*$$

where $\rho^2 = R^2 + x^2$.

With relatively small values of a and b the calculation of the field strength components of a single coil is carried out from [4]

$$H_x = 0\ 2\pi I w \frac{R^2}{(R^2 + x^2)^{\frac{3}{2}}}\left[1 - \frac{3}{4}\frac{y^2}{(R^2 + x^2)^2}(R^2 - 4x^2)\right], \quad (2)$$

$$H_y = 0.3\pi I w \frac{R^2 xy}{(R^2 + x^2)^{\frac{5}{2}}}\left[1 + \frac{5}{8}\frac{y^2}{(R^2 + x^2)^2}(3R^2 - 4x^2)\right]. \quad (3)$$

Hence, for the center of the coil (x = 0, y = 0)

$$H_{x0} = \frac{0.2\pi I w}{R}, \quad H_{y0} = 0. \quad (4)$$

On the basis of (2), (3) and (4) we have for the points lying on the axis of the coil (x-axis of the magnetic field, y = 0):

* Here, as henceforth, H is in oersteds, I in amperes, and all dimensions in centimeters.

$$\left[\frac{H_x}{H_{x0}}\right]_{y=0} = \frac{R^3}{(R^2+x^2)^{\frac{3}{2}}} = \frac{1}{\left[\sqrt{1+\left(\frac{x}{R}\right)^2}\right]^3}, \tag{5}$$

and for the points lying in the plane of the central cross section of the coil (x = 0):

$$\left[\frac{H_x}{H_{x0}}\right]_{x=0} = 1 + \frac{3}{4}\left(\frac{y}{R}\right)^2. \tag{6}$$

It is possible to calculate that by increasing the distance from the plane of the coil along the x-axis up to $x = 0.2\,R$ the field strength is decreased by about 5%, and for $x = 0.25\,R$ it is decreased by 9% at a distance from the center along the plane of the coil of $y = 0.2\,R$, the field strength increases by 3% and at distance of $y = 0.25\,R$ by approximately 5%.

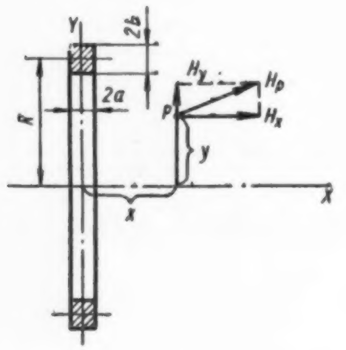


Fig. 1.

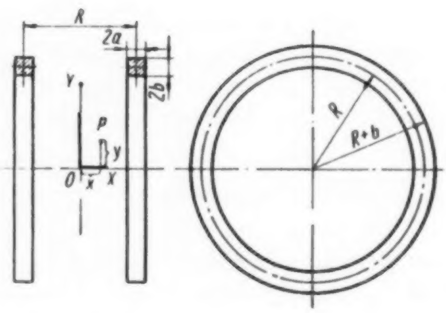


Fig. 2.

Thus in fulfilling the recommendation [3] that the diameter of the coil should exceed the dimensions of the instrument under test at least by a factor of 4, the nonuniformity of the field in the volume occupied by the instrument is kept within 5%.

A double coil with a distance between the two coils equal to their radius provides a much more uniform field as it will be seen from the following.

It is known [4] that if the ratio of the transverse dimensions of the winding is $a/b = \sqrt{31/36}$, the corrections to the formulas of the field strength components of the Helmholtz rings are small and the field strength of such coils (Fig. 2) is determined from the formulas

$$H_x = \frac{3.2\pi I w}{5\sqrt{5}\,R}\left[\left(1 - \frac{b^2}{15R^2}\right) - 0.144\frac{1}{R^4}(8x^4 - 24x^2y^2 + 3y^4)\right], \tag{7}$$

$$H_y = \frac{3.2\pi \cdot 1.8 \cdot 16 I w}{5\sqrt{5} \cdot 25 \cdot 2R^5}\, xy\,(4x^2 - 3y^2), \tag{8}$$

where $w$ is the number of turns in each ring of the double coil. Hence for the center of the coil

$$H_{x0} = \frac{3.2\pi I w}{5\sqrt{5}\,R}\left(1 - \frac{b^2}{15R^2}\right),\quad H_{y0} = 0, \tag{9}$$

or, since normally $b^2 \ll 15R^2$,

$$H_{x0}=\frac{3.2\pi Iw}{5\sqrt{5}\,R}. \tag{9a}$$

From (7), (8), and (9) we obtain the following relations between the field strength components $H_x$ and $H_y$ at some point P with coordinate x and y with respect to the intensity $H_{x0}$ at the center of the field:

$$\frac{H_x}{H_{x0}}=1-0.144\left[8\left(\frac{x}{R}\right)^4-24\left(\frac{x}{R}\right)^2\left(\frac{y}{R}\right)^2+3\left(\frac{y}{R}\right)^4\right]. \tag{10}$$

$$\frac{H_y}{H_{x0}}=0.576\,\frac{x}{R}\cdot\frac{y}{R}\left[4\left(\frac{x}{R}\right)^2-3\left(\frac{y}{R}\right)^2\right]. \tag{11}$$

Calculations from (10) and (11) show that in the volume determined by the maximum coordinates $x = 0.5R$ and $y = 0.5R$, the field strength component $H_y$ does not exceed several tenths of a percent and component $H_x$ changes at the most by 5%.

Thus, for approximately the same nonuniformity of the field occupied by the tested instrument and amounting to 5%, the mean radius of the rings of a double coil can be half as large as that of a single coil.

The ratio of single and double coil radii amounts to 3.5 in a given field of 2% nonuniformity.

The above reasoning leads to very important conclusions outlined below.

The basic dimension of the coil, its mean radius R, is determined by the over-all dimensions of the instruments to be measured. Next, on the basis of (4) or (9a) the ampereturns Iw required for providing a magnetic field of strength $H_{x0}$ are determined.

The selection of the value of I and w separately is based on the following practical considerations.

The winding wire is selected according to the current I from the permissible current density j which is constant for these conditions (normally at 2.5-3 amp/mm$^2$). In the first approximation for given ampereturns Iw, the voltage across the coil is inversely proportional to the current. Hence, with a small current it becomes necessary to use a high voltage supply and raise the insulation of the coil and other components in order to provide safe operation. On the other hand the raising of the current requires the use of a low voltage source of supply designed for large currents (if dc is used, large storage batteries are required). It is, therefore, advisable to choose current I in the range of 0.5 to 2 amp. This determines the corresponding value of w.

The power $P_a$ supplied to the coil can be determined as a function of $H_{x0}$, R, and j independently of I or w. Thus for dc and a single coil we have:

$$P_a=10H_{x0}R^2\rho_s j, \tag{12}$$

where $\rho_s$ is the resistivity of the winding wire.

A comparison of (4) and (9a) shows that with the same mean radius R of the coils and the same current I, the single coil must have more turns $w_0$ than each coil $w_d$ of the double pair, namely:

$$\frac{w_0}{w_d}=1.43 \tag{13}$$

(although the total number of turns of a double coil $2w_d$ is 1.4 times greater than that of a single coil $w_0$).

Since the inductance of a coil is proportional to the square of the number of turns, the other conditions remaining equal ($H_{x0}$, R and I), the single and double coils have approximately the same reactance (considering that for a double coil M << L), and the effective resistance of the double coil is approximately 1.4 times greater than that of a single coil. The power consumed, especially in ac working, by single and double coils of the same mean radii and passing the same current is about the same.

In order to establish a field of a given strength the same power will also be required if the single and double coils have the same number of turns in each of the windings of similar wire. Then the current in the single coil will be 1.43 times greater than the current in the double coil. If however, $\underline{j}$ is kept constant, the impedance of the double coil will be greater and a larger power will be required to produce the same field as in the single coil (this difference decreases with a rising frequency).

However, due to a considerably more uniform distribution of the field, the mean diameter of the double coil can be made smaller than that of a single coil. The advantages of the double coil now become apparent.

Let us make a comparison when their radii have the ratio of 2.

For equal currents in the coils,the double coil will have half the number of turns of a double coil with a radius equal to that of a single coil. Its effective resistance will be reduced to 1/4 and inductance to 1/8. Since, for high-frequency currents the reactance of the coil is of primary importance,the voltage at the source and hence the power required to supply this coil will also be reduced to 1/8.

When the equipment is designed to work on dc or commercial frequency supplies, the power of the source of supplies is not important, but for an equipment designed to work at high frequencies this factor may become very important. It follows from the above that for providing a magnetic field at high frequencies a double coil should be used.

The larger the size of the coil,the greater is the power required for the establishment of a field of the same strength. If at the same time the same current is used the voltage across the coil rises considerably.

With an increased frequency, and the other conditions remaining the same, the voltage also rises.

There may be many instances at higher frequencies when the voltage required to be supplied to the coil and sometimes the power exceed considerably the voltage and power of the source of supplies. In such a case it is recommended to connect in series with the coil a capacitor C (Fig. 3),in order to produce a series-tuned circuit at the required frequency,thus providing the possibility of using a low-power, low-voltage source of supplies.

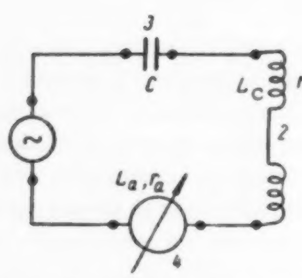


Fig. 3. 1) Supply source with a controlled output voltage; 2) coil for providing the magnetic field; 3) capacitor; 4) ammeter for checking the current in the coil.

The voltage of the source of supplies $U_s$ is at resonance considerably lower than that across the coil or capacitor and is determined by the voltage drop across the effective series-resistance of the circuit:

$$U_s = I\,(r_c + r_a), \tag{14}$$

where $r_c$ and $r_a$ are the active resistances of the coil and the ammeter (Fig. 3).

The capacitance C required for producing resonance at frequency $\omega$ is found from the expression:

$$\omega\,(L_c + L_a) = \frac{1}{\omega C}, \tag{15}$$

where $L_c$ and $L_a$ are the inductances of the coil and the ammeter respectively.*

In practice,when a tuning capacitance is selected it is necessary to use parallel capacitors. In selecting these capacitors,it should be kept in mind that they will work at a frequency of $f = \omega/2\pi$ and a voltage of

$$U_c = I\,\frac{1}{\omega C}. \tag{16}$$

* For a double coil, $L_c = 2(L + M)$; $L = 1.26 \cdot 10^{-8} \cdot R\omega^2 \left(\ln \frac{8}{2a + 2b} - 0.5\right)$; $M = 0.5 \cdot 10^{-8} \cdot R\omega^2$; L and M in henries, R, $\underline{a}$ and $\underline{b}$ in centimeters.

In selecting capacitors for the parallel connection, it should be remembered that capacitors should be used at a lower ac voltage (according to frequency) than the working voltage marked on them [5].

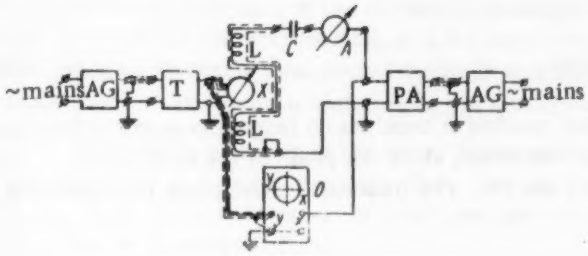


Fig. 4. AG) Audiofrequency generator; T) amplifier or transformer; or a combined use of an amplifier and transformer; X) the ammeter or voltmeter under test; PA) power amplifier; L) coil for the establishment of an external magnetic field; C) capacitor (unit); A) ammeter for checking the current in the coil; O) cathode-ray oscilloscope.

From the above it follows that the selection of capacitors for a double coil is simpler since its voltage is lower than that of a single coil.

From the examination of the power characteristics, especially at higher frequencies, it follows that for the establishment of an external uniform field for testing instruments it is advisable to use a double Helmholtz coil.

In conclusion, let us examine the technique of testing electrical measuring instruments for the effect of external magnetic fields.

Tests at higher frequencies when there are no phase shifting devices are carried out in the same manner as at 50 cps [1]. However, it is simpler to test at commercial or higher frequencies by means of the so-called beating method, which at the same time is the only possible method in the absence of phase shifting devices.

For the beating method it is necessary to have two sources of supplies, one for the coil and the other for the instrument under test; both of the same nominal frequency with one of them having a smooth frequency control so as to be able to measure the difference of the two generators with an accuracy of one-tenth of a cycle per second.

The essence of the beating method consists in making the frequencies of the sources of supply of the coil and the instrument differ by a small quantity, which will make the effect of the field on the instrument the same as if the external field were of the same frequency as that of the current or voltage measured by the instrument, but with a phase changing slowly with respect to the phase of the variable measured by the instrument. The variation of the phase of the field occurs at the difference frequency, the beat frequency, which can be seen from the following consideration.

The sinusoidal voltage across the instrument under test or the current flowing through it is equal at any instant to:

$$a_x = A_x \sin \omega t, \tag{17}$$

where $a_x$ is the instantaneous value of the current or the voltage; $A_x$ is the amplitude of the current or the voltage; $\omega$ is the angular frequency of the current or the voltage equal to the frequency of the supply voltage.

The strength of the magnetic field when current is flowing through the coil also varies sinusoidally. Since the frequency of the coil supply differs slightly from that of the instrument supply in the beat method of measurement, the field strength at any instant will be equal to:

$$H = H_{max} \sin [(\omega + \Delta\omega) t + \varphi_i]. \tag{18}$$

where $H_{max}$ is the amplitude of the field strength due to the amplitude of the current flowing through the coil and calculated from formulas (4) or (9a); $\varphi_i$ is the initial phase of the field with respect to the phase of the variable measured by the instrument (at the instant t = 0).

From (18) we have

$$H = H_{max} \sin [\omega t + (\Delta\omega t + \varphi_i)]. \tag{19}$$

Angle $(\Delta\omega t + \varphi_i)$ passes through all the values from $\varphi_i$ to $(2\pi + \varphi_i)$ in the time $\underline{t}$ from 0 to $2\pi/\Delta\omega$; with a further increase in the time this angle changes, passing through all the values from 0 to $2\pi$.

It will be seen from (19) that the field strength varies according to a sinusoidal law with respect to frequency $\omega$, but with a periodically changing phase:

$$\varphi = \varphi_i + \Delta\omega t. \tag{20}$$

Thus, when the instrument is tested by means of the beat method it becomes no longer necessary to find the worst phasing of the field with the variable measured by the instrument, since the phase of the field varies periodically passing through all the possible values between 0 and $2\pi$. The frequency of the phase measurements is the beat frequency, $\Delta\omega$.

The required frequency is adjusted on the controlled generator very simply by observing the difference frequency on the screen of the cathode-ray oscilloscope as the movement of the Lissajous figure, a circle or an ellipse.

An example of the circuit arrangement for testing voltmeters or ammeters for the effect of an external magnetic field by means of the beat method is shown in Fig. 4.

When measuring highly sensitive equipment (for instance detector-type voltmeters with a very small full-scale deflection current), it is necessary to screen the instrument from the possible leakage from the coil winding which is at a high voltage. It is advisable to screen the coil (when it is being manufactured) in the manner shown in Fig. 4.*

Owing to the capacitative coupling between the turns of the coil and between the winding and the screen, a considerable compensation of the inductive current by the capacitative current is possible, making the current in the coil noticeably larger than the one read on the ammeter A of the circuit in Fig. 4. At higher frequencies, over 8 kc it is impossible, therefore, to use formulas (4) and (9a) (the error may exceed 5%) for determining the field strength by the current read on ammeter A.

It is necessary to determine experimentally the ammeter readings corresponding to a given field strength. This can be done by measuring the field strength with a multiwinding test coil whose emf is read on a tube voltmeter. Since the emf induced in the test coil is proportional, in a permanent position of the coil, to the field strength and frequency, and with a constant field strength it will be proportional to frequency. At higher frequencies, however, it is usual in testing instruments to set the field strength at a limiting frequency and vary the field strength inversely proportionately to the frequency, hence under these conditions the emf induced in the test coil should remain constant (constant voltmeter readings). Moreover at these high frequencies the readings of the ammeter will be as a rule a little higher than those calculated from (4) and (9a).

If the readings of the instruments under the effect of an external field depend among other factors also on the phase relation between the field and the variable measured by the instrument under test, the readings of the instrument will vary periodically if it is tested by means of the beat method. The moving part of the instrument will then oscillate about some position which is determined by the value of the variable measured by the instrument (in the absence of the external field). The greatest deviation of the moving part of the instrument from the above value corresponds to the least favorable phase of the field, for which the effect of the field should be measured.

The forced oscillations of the instrument's moving part may be accompanied by amplitude distortions. These distortions will decrease with a decreasing ratio of the forced-oscillations frequency to the natural (resonance) frequency of the moving part.

In order to prevent excessive amplitude distortions in the oscillations of the instrument's moving part, when measuring by means of the beat method, it is necessary to make the beat period $T_b = 1/\Delta f$ (where $\Delta f = \Delta\omega/2\pi$)

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*In the absence of a screened coil the instrument should be screened from all the sides (in addition to the leads). This screen, however, should not decrease the strength of the magnetic field in the place occupied by the instrument and should, therefore, be made of very thin material cut into strips (for instance capacitor tin foil) and should not form complete loops. The screen of the coil must not decrease its magnetic field either.

at least 3 times larger than the effective damping time of the instrument.

Under the above condition the amplitude distortions will be unnoticeable, i.e., there will be practically no error in determining the effect of the external magnetic field on the readings of the tested instrument.

When the variations of the instrument readings are being determined under the effect of an external magnetic field by means of the beat method, it is necessary first to set the required field strength and beat frequency, and then find the least favorable direction of the field with respect to the instrument (by turning the instrument or the coil) which produces the greatest variation in the instrument readings.

The largest deviation of the tested instrument's pointer from the position of balance which it occupied in the absence of an external magnetic field (half the swing of the pointer in the case when the reading is affected by the phase of the field) serves to determine the relative referred variation of the readings of the instrument under the effect of an external field:

$$\beta_e = \frac{\Delta\alpha}{A_f} \cdot 100\%. \tag{21}$$

where $\Delta\alpha$ is the maximum variation in the instrument readings under the effect of an external field; $A_f$ is the instrument's full-scale deflection at which the tests were carried out.

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# A MEASURING GALVANOMETRIC AMPLIFIER WITH SEMICONDUCTOR THERMISTORS


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In recent years galvanometric amplifiers are being increasingly used for amplifying small dc currents and voltages.

The input unit of these amplifiers consists of sensitive moving coil instruments, the rotation of whose coil is transformed by means of special converters into electrical signals.

The most commonly used are photogalvanometric amplifiers (PGA) which use a photoelectric method of converting the coil movement by means of a photocell or photovaristor. The PGA possesses high sensitivity and accuracy and a comparatively small zero drift [1, 2].

One of the most cardinal defects of the PGA is the use of an optical system. This system requires painstaking adjustment, it is very sensitive to dirt and increases the over-all size of the instrument.

The photoelectric method, however, is not the only one used for converting purposes in galvanometric amplifiers. On A. F. Gordovskii's suggestion [3] the ZIP plant has been making for the last few years thermoradiation galvanometric null indicators T-316, which consist of a sensitive miniature galvanometer on torsion suspensions with a nichrome wire heater attached to its moving coil. When the coil rotates the heater is displaced relative to the junction of two stationary thermocouple batteries, which are connected in opposing series on both sides of the heater. A microammeter is connected to the output terminals of the thermocouples. When the heater is displaced from its middle position, the temperature of the junctions of one thermocouple battery increases and of the other decreases. The variation of the thermal emfs of the batteries produces a current which is registered on the microammeter. Suggestions were made [4] on replacing the differential thermocouple battery by a bridge circuit, with sensitive thermal semiconductor resistors (thermistors) connected in two of the bridge arms. The use of a bridge circuit with thermistors provides an increased output voltage and a higher gain in comparison with the corresponding parameters of a PGA.

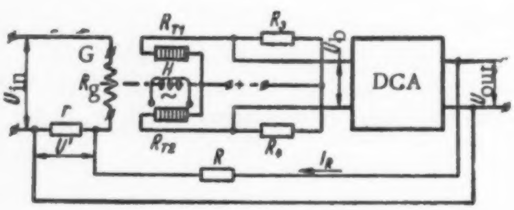

Fig. 1.

The above thermoradiation galvanometric amplifiers (TGA) provided a high sensitivity, but were not accurate, since their circuit did not include any devices for stabilizing the gain.

Below we describe a TGA which uses thermistors, and includes gain stabilization by means of a large negative feedback which provides, with certain other additional devices, a precise as well as a sensitive instrument.

Principle of operation of a thermistor TGA used for voltage amplification. The amplified voltage $U_{in}$ (Fig. 1) is fed through a feedback resistor r to the coil of the sensitive galvanometer G. The moving part of the latter carries a heater H, fed by an ac current from an appropriate winding of the mains step-down transformer.

Two stationary thermistors $R_{T1}$ and $R_{T2}$ are placed near the heater and connected to the arms of a bridge circuit. The parameters of the bridge circuit are chosen so as to have the bridge balanced in the middle position of the heater, $U_b = 0$. The variation in the position of the heater when the coil rotates produces a rise in the temperature of one of the thermistors and a drop in that of the other. This unbalances the bridge. The output voltage $U_b$ of the bridge is amplified by the dc amplifier (DCA). The large gain of the amplifier makes it possible to use a large negative feedback by means of resistors R and r.

Let us introduce the following notations:

$U_{out}$ is the TGA output voltage; I is the galvanometer circuit current; $R_G$ is the galvanometer resistance; $\alpha$ is the rotation angle of the galvanometer coil; $S = \alpha/I$ is the sensitivity of the galvanometer; $K_1 = U_b/\alpha$ is the sensitivity of the bridge with the thermistors; $K_2$ is the gain of the dc amplifier; $I_R$ is the feedback current; U' is the voltage across resistor r; and $\beta = U'/U_{out}$ is the feedback factor.

It is easily seen that

$$U_{out} = ISK_1K_2 = IK,$$

where $K = SK_1K_2$, and

$$IR_G = U_{in} - \beta U_{out}.$$

Thence we obtain the well-known expression for the relation between the output and the input voltages:

$$U_{out} = \frac{U_{in}\dfrac{K}{R_G}}{1+\beta\dfrac{K}{R_G}}, \text{ or } U_{out} = \frac{U_{in}}{\beta}\cdot\frac{1}{1+\dfrac{1}{\beta\dfrac{K}{R_G}}}. \tag{1}$$

Since $U' = (I + I_R)\,r$ and $U_{out} = I_R(R + r) + Ir$; $\beta = \beta_0 \dfrac{1 + C}{1 + \beta_0 C}$, where $\beta_0 = \dfrac{r}{R + r}$ and $C = \dfrac{I}{I_R}$.

From the relationship $IK = I_R(R + r) + I_r$, we obtain:

$$C = \frac{I}{I_R} = \frac{R+r}{R} \cdot \frac{1}{\frac{K}{r} - 1} = \frac{1}{\beta_0\left(\frac{K}{r} - 1\right)}.$$

Since in practice $\beta_0$ is small and $\beta_0 K/r$ is large, we can assume that

$$C = \frac{1}{\beta_0 \frac{K}{r}}\ ;\ \beta = \beta_0(1+C).$$

By substituting these expressions in (1) we have:

$$U_{out} = \frac{U_{in}}{\beta_0(1+C)} \cdot \frac{1}{1 + \frac{1}{\beta_0(1+C)\frac{K}{R_G}}},$$

or

$$U_{out} = \frac{U_{in}}{\beta_0} \cdot \frac{1}{1 + \frac{1}{\beta_0 \frac{K}{r}} + \frac{1}{\beta_0 \frac{K}{R_G}}}.$$

Considering that $\dfrac{1}{\beta_0 \frac{K}{r}} + \dfrac{1}{\beta_0 \frac{K}{R_G}}$ is a small quantity we can finally write:

$$U_{out} = \frac{U_{in}}{\beta_0}\left(1 - \frac{1}{\beta_0 \frac{K}{r}} - \frac{1}{\beta_0 \frac{K}{R_G}}\right) = U_{in} K\ . \qquad (2)$$

Expression (2) shows the relation of the effective gain of the TGA to the parameters of the input circuit ($R_G$ and r) and the gain of separate elements of the circuit ($K = SK_1K_2$). In this circuit, the same as in all the circuits with a large negative feedback, even considerable variations of K and $R_G$ affect but little the effective gain of the amplifier providing K is sufficiently large.

Since the sensitivity of the galvanometer in the above instrument is limited by the parameters of modern portable galvanometers, it is necessary to raise the sensitivity $K_1$ of the thermistor bridge and, if required, use an additional output amplifier in order to obtain a sufficiently high value for K. It should be noted that if one does not aim at a small value of $\beta_0$ (a large value of the effective gain $K_e$) and does not require a high precision, the required value of K can be obtained without a dc amplifier (DCA).

Selection of thermistors and bridge parameters. In order to obtain a high sensitivity of the thermistor bridge and a suitable speed of operation, the thermistors should possess as high a temperature coefficient as possible and the smallest possible time constant. An important part is also played by the thermistor dimensions, which control not only the time constant but also the required power in the heater. It will be shown later that it is desirable to have a largest possible maximum on the voltampere characteristic of the thermistors taken in their cold state. Among the large number of thermistor types mass-produced by our industry [5, 6] the most suitable with respect to

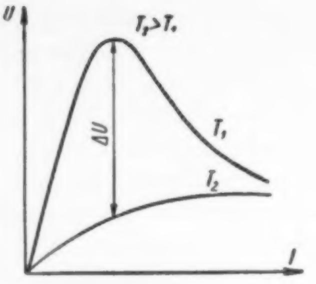


Fig. 2.

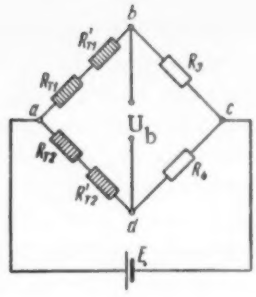


Fig. 3.

the above requirements are thermistors type TSh-1 [6], which were, therefore, used in the instrument. Thermistors type TSh-1 consist of semiconductor cylinders 0.15 mm in diameter and 1.5 mm long. Their leads are made of platinum wire 25 μ in diameter. Typical voltampere characteristics of these thermistors for various air temperatures are shown in Fig. 2. The method of connecting the thermistors in the bridge circuit is shown in Fig. 3, where $R_T$ are the thermistors and R the constant linear resistors. In order to raise the output voltage $U_b$ of the bridge and facilitate the selection of thermistors with suitable characteristics, two series thermistors were connected in each arm of the bridge. The bridge is supplied from the ac diagonal. The feeding of the bridge from the bd diagonal may lead under certain conditions to a rise in the current through the thermistors to excessive values.

The value of the operating current in the thermistors is the determining factor for the sensitivity of the bridge. It will be seen from Fig. 2 that in order to obtain the largest possible variation (ΔU) in the voltage across the thermistor with temperature variations of the surrounding media between $T_1$ and $T_2$, it is necessary for the operational point of the thermistor characteristic to be near its maximum. It is also easy to see that the sensitivity to temperature variations will rise with the maximum ordinate of the voltampere characteristic. Having determined from the thermistor characteristic a suitable value for the operating current, it is easy to select the required value for resistance R and the feeding voltage in order to obtain the desirable operating condition.

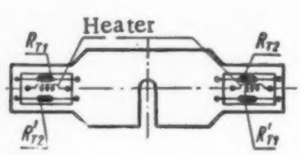


Fig. 4.

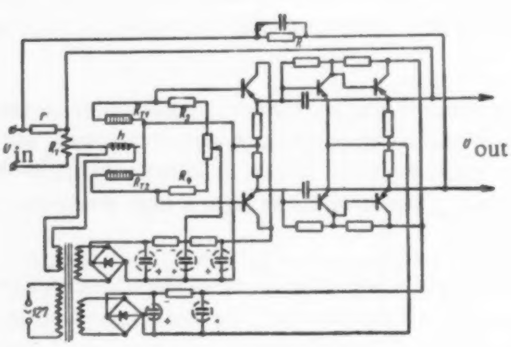


Fig. 5.

Selection of a galvanometer. In selecting a galvanometer it is important to choose not only a correct sensitivity, but also a suitable damping which must be sufficiently high. A high damping will not only facilitate the stabilization of the system by means of feedback, but will also provide a higher value of the gain for which the system will remain stable without any extra correcting links. Moreover, high damping makes the galvanometer, and hence the whole TGA, more vibration-proof, thus improving considerably its operational properties. Of the mass-produced galvanometers, those used in the photogalvanometric amplifiers, types F-12 and F-17 and the one used in the null indicator T-316 are the most suitable for the above conditions.

Description of the constructed thermistor TGA. Theoretically, two types of designs are possible for a thermistor galvanometer-bridge unit: with the heater fixed to the moving part of the galvanometer and stationary thermistors; and with the thermistors fixed to the moving part and a stationary heater.

Both designs have their advantages and disadvantages. The fixing of the heater to the moving part of the galvanometer has already been adopted by the industry (instrument T-316), however, in this instance it is necessary to

supply the heater with a current which amounts to several dozen milliamperes. Moreover the heater increases considerably the moment of inertia of the moving part and decreases its speed of operation.

With a stationary heater no difficulties arise either with the type or size of the feeding current. Neither is there any difficulty in supplying current to the moving thermistors since its value does not exceed 1 ma. In this case, however, there remains a certain rise in the inertia of the moving part of the galvanometer.

In the experimental model of the GCA the thermistors were fixed to the moving part of a galvanometer from a PGA type F-12 which had a coil resistance of 22 ohms and a critical resistance of 400 ohms. The thermistors were mounted on a mica plate as shown in Fig. 4. The plate was fixed to the galvanometer coil and the current supplied to the thermistors by means of three light flexible leads. The stationary heater consisted of two equal parts connected in series.

When the moving part of the galvanometer is displaced away from its middle position, the two diagonally opposite thermistors, which are connected in series, are heated up (for instance $R_{T1}$ and $R'_{T1}$) and the other two are cooled (for instance $R_{T2}$ and $R'_{T2}$). The bridge becomes unbalanced and voltage $U_b$ appears on the diagonal (Fig. 3).

The DCA operates with transistors connected in a three stage push-pull circuit. The first stage consists of an emitter follower with an input resistance of the order of 500 kilohms. The second stage consists of a common emitter voltage amplifier. Its gain amounts to 300. The third stage is an emitter follower used for reducing the output impedance of the DCA. If a high power output is required, the last stage should consist of power transistors type P3 or P4. The second and third stages are included in a negative feedback, which reduces considerably the high frequency noise of the transistors and the ac component due to the ripple of the supply voltage.

The schematic circuit of the TGA is shown in Fig. 5. For the convenience of representation the heater, instead of the coil with thermistors, is shown as being mobile.

The instrument has the following characteristics:

| | |
|---|---|
| nominal input voltage | ±1 mv |
| nominal output voltage | ±10 v |
| nonlinearity of the static amplitude characteristic | ±0.2% |
| operational time for a rectangular pulse of the nominal input voltage | 0.2-0.3 sec. |
| the noise level referred to the input, does not exceed | 1 μv |
| the zero drift for 24 hr, referred to the input, does not exceed | 5 μv |
| the TGA is fed from ac mains | 127 v |
| its power consumption is | 2 w |
| its over-all dimensions are, including the power pack | 160 × 120 × 110 mm |

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# HIGH AND ULTRAHIGH FREQUENCY MEASUREMENTS

## A STANDARD CAPACITOR FOR FREQUENCIES UP TO 200-300 Mc

A. L. Grokhol'skii

Translated from Izmeritel'naya Tekhnika, No. 6, pp. 43-47, June, 1960

The majority of two-terminal capacitors, widely used as capacitance standards at audio- and low radio-frequencies, cannot be used at high frequencies without additional investigation of the relation of their capacitance to frequency.

For conducting such investigations special reference high-frequency capacitance standards are required, whose construction is determined by calculations of the effective capacitance at a given frequency. This requirement is met mostly by capacitors with flat,parallel, spherical, disk or coaxial plates which were often used for low-frequency calculated reference capacitors.

The majority of the formulas used for their calculations were derived with the assumption that their linear dimensions were considerably smaller than the wavelength for which they were designed. This assumption no longer holds for high frequencies. Moreover, at high frequencies, the calculation of capacitance is usually made more complex by the effect of a nonuniform field in connecting devices(by means of which the capacitors are connected to the circuit).

Investigations carried out at the Novosibirsk State Institute of Measures and Measuring Instruments (NGIMIP) showed the coaxial cylindrical shape, whose capacitance and its relation to frequency can be calculated precisely, gave the best results. The error due to the nonuniformity of the field in the connecting devices is small or completely absent since these devices form part of the capacitor.

Coaxial capacitors can be connected into sets subject to known laws of adding capacitances, since several interconnected capacitors form a new single uniform capacitor. It is difficult to make such connections at high frequencies with capacitors of other shapes, whose law of adding capacitances is difficult to establish. Components of coaxial capacitors of a cylindrical shape are inexpensive and can be made with great precision.

We made high-frequency capacitors of several types to suit the measuring equipment and frequency range for which they were designed.

For laboratory work the most precise construction was found to consist of two copper cylinders which formed the inner and outer electrodes, with the gap between them fixed by means of needle-shaped quartz insulators, secured to the outer electrode by means of bleed screws. Three button-type insulators,fixed at each end of the capacitor and spaced by 120°,hold securely the outer electrode. This construction stands up to repeated connections, preserving the low frequency value of the capacitance within the measurement limits.

Investigations have shown that these insulators placed at the open end of the capacitor introduced at high frequencies disturbances which do not exceed a few hundredths of a $\mu\mu f$. The insulators at the input of the capacitor do not affect the accuracy in determining the effective capacitance.

In less precise constructions it is possible to replace the quartz buttons by dielectric screws which are normally used to fix the internal conductor in measuring lines. Screws made of organic glass proved to be stable in operation.

One of the measuring-type capacitors KVCh-2 is shown in Fig. 1. It consists of two cylindrical electrodes 1 and 2 separated from each other by a ring-shaped steatite insulator 4. The insulators and electrodes are secured

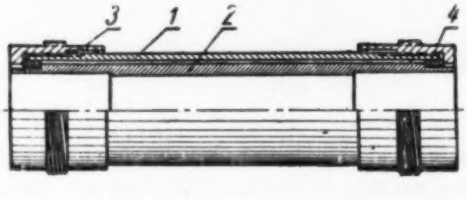

Fig. 1.

by means of two end sleeves 3. The sleeves and the end portion of the internal electrode form the connecting device by means of which the capacitor is connected to the measuring equipment and other capacitors.

The theory of the capacitor. The high-frequency capacitors developed by the NGIMIP consist of unloaded, coaxial, uniform lines.

The input impedance of such a line is determined from the formula

$$Z_i = W \operatorname{cth} \gamma l, \tag{1}$$

where W is the impedance of the line; $\gamma = \beta + j\alpha$ is the propagation constant of the wave; $\beta$ is the attenuation constant; $\alpha$ is the phase-shift constant; and $l$ is the length of the line.

If in designing the capacitor measures are taken to decrease losses, the input admittance of the line with small losses can be calculated from the well-known formula:

$$Y_{in} = \frac{\beta l + j \operatorname{tg} \alpha l + j\dfrac{\beta^2 l^2}{2} \operatorname{tg} \alpha l}{\left(1 + \dfrac{\beta l}{2} + j\beta l \operatorname{tg} \alpha l\right) W} = B + jA, \tag{2}$$

where

$$W = W'\left[1 + \frac{1}{2}\left(\frac{\beta_c}{\alpha'} + 3\frac{\beta_d}{\alpha'}\right)\left(\frac{\beta_c}{\alpha'} - \frac{\beta_d}{\alpha'}\right) - j\left(\frac{\beta_c}{\alpha'} - \frac{\beta_d}{\alpha'}\right)\right]; \tag{3}$$

$$\alpha = \alpha'\left[1 + \frac{1}{2}\left(\frac{\beta_c}{\alpha'} - \frac{\beta_d}{\alpha'}\right)^2\right]; \ \alpha' = \omega\sqrt{LC} \tag{4}$$

$W'$ and $\alpha'$ are the impedance and the phase constant of a line without losses.

$\beta_c$ and $\beta_d$ are the attenuation constants due to the losses in the metal and the dielectric respectively, so that $\beta = \beta_c + \beta_d$.

It follows from (3) and (4) that for a certain relation between $\beta_c$ and $\beta_d$ they will not affect W or $\alpha'$.

In the further treatment of this problem we shall only examine the extreme case when there are only losses in the metal and $\beta = \beta_c$.

In substituting in (2) the values of (3) and (4) and following simple transformations, we obtain:

$$B = \left[\frac{2}{3}\beta_c \alpha'^2 l^3 \left(1 + \frac{4}{5}\alpha'^2 l^2\right)\right]\frac{1}{W'}, \tag{5}$$

$$A = \left(\tan \alpha' l - \frac{8}{15}\beta_c^2 \alpha'^3 l^5\right)\frac{1}{W'}. \tag{6}$$

Let us now examine in greater detail expression (6) which represents the input susceptance of an open line. The second term of this expression for lines made of copper conducting surfaces, which have geometrical dimensions similar to those of the capacitors given below, has an absolute value of:

$$\frac{8}{15}\beta_c^2 \alpha'^3 l^5 \simeq 1.10^{-6} \tag{6'}$$

In view of the smallness of the second term, the expression for the susceptance will have the form

$$A = \frac{1}{W'} \tan \alpha' l. \tag{7}$$

It is known that the input admittance of an actual open line with a length smaller than one-quarter of the wavelength under consideration is capacitative. In such a case it is possible to represent the line as a capacitor whose effective capacitance is

$$C = \frac{\tan \alpha' l}{\omega W'}, \tag{8}$$

where

$$\omega = 2\pi f;$$

$$W' = \sqrt{\frac{L_0}{C_0}\left(1 + \frac{\Delta L}{L_0}\right)};$$

$$\alpha' = \omega \sqrt{C_0 L_0 \left(1 + \frac{\Delta L}{L_0}\right)};$$

$L_0$ is the inductance per unit length of line for a depth of current penetration of $\delta \to 0$; $C_0$ is the capacitance per unit length of line for $\delta \to 0$; and $\Delta L$ is the variation of unit length inductance for $\delta \neq 0$.

Having substituted the values of $W'$ and $\alpha'$ in (8) and after certain transformations, we obtain an expression for the effective capacitance

$$C = C_0 l \, [1 + p + qS], \tag{9}$$

where $C_0 l$ is the capacitance of the capacitor at 1000 cps

$$p = \frac{1}{3}\left(\frac{2\pi l}{\lambda}\right)^2 + \frac{2}{15}\left(\frac{2\pi l}{\lambda}\right)^4 + \frac{17}{315}\left(\frac{2\pi l}{\lambda}\right)^6, \qquad q = \frac{1}{3}\left(\frac{2\pi l}{\lambda}\right) + \frac{4}{15}\left(\frac{2\pi l}{\lambda}\right)^4 + \frac{17}{105}\left(\frac{2\pi l}{\lambda}\right)^6, \tag{10}$$

$$S = \frac{\Delta L}{L_0}.$$

It follows from (9) that the effective capacitance of the capacitor at a high frequency is determined from the static capacitance equal to $C_0 l$, the frequency correction p and corrections q and S which account for the variations of the effective capacitance due to changes in the inductance of the capacitor with frequency.

The static capacitance $C_0 l = C_s$ can be calculated with an error of 0.1-0.2% according to well-known formulas which take into account the geometrical dimensions of the capacitor and the contacts of the inter-electrode space.

In practice, it is better not to calculate the static capacitance but to measure it at 1000 cps by means of low-frequency capacitance standards, which is quicker and simpler. This technique is used in the Institutes of the Committee of Standards, Measures and Measuring Instruments. Moreover, even with rather low requirements of accuracy in the manufacture and assembly of the capacitor it is possible to obtain its real value with an error of 0.003-0.01%.

The frequency correction of the capacitance of a uniform, coaxial capacitor depends only on the ratio of the geometrical length of the capacitor to the wavelength used for measurements, i.e., on $l/\lambda$. This ratio does not depend on the impedance or the low-frequency capacitance of the capacitor. This relation, $p = f(l/\lambda)$ is given in Fig. 2.

The value of the capacitance correction q as well as that of p depends on the ratio $l/\lambda$ but does not depend on the impedance of the capacitor. The relation $q = \varphi(l/\lambda)$ is given in Fig. 3.

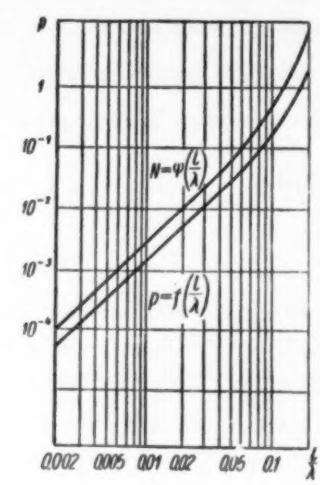


Fig. 2.

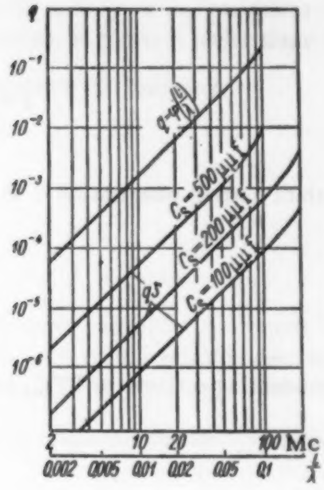


Fig. 3.

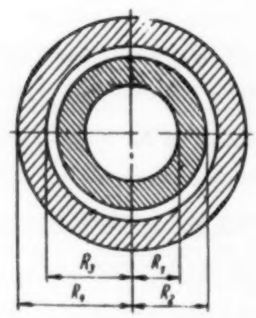


Fig. 4.

The correction factor $S = \Delta L/L_0$ depends on the depth of current penetration into the metal of the capacitor electrodes. The inductance of the coaxial capacitor changes with the depth of penetration from the maximum value for a direct current to its minimum at UHF when $\delta = 0$.

In order to calculate the inductance of a coaxial capacitor with respect to frequency, special formulas were derived since the generally accepted formulas do not provide the required accuracy.

The unit length inductance of a coaxial capacitor which has a cross section shown in Fig. 4 and is made of nonferromagnetic materials is represented at low frequencies by:

$$L=2\left[\ln\frac{R_3}{R_2}+\ln\frac{R_4}{R_3}+\frac{R_3^2}{2\left(R_4^2-R_3^2\right)}-\frac{R_1^2}{2\left(R_2^2-R_1^2\right)}+\right. \left.+\frac{R_1^4}{\left(R_2^2-R_1^2\right)^2}\ln\frac{R_2}{R_1}-\frac{R_3^4}{\left(R_4^2-R_3^2\right)^2}\ln\frac{R_4}{R_3}\right]. \quad (13)$$

At high frequencies when the depth of current penetration is small the following formula will hold:

$$L=2\left(\ln\frac{R_3}{R_2}+\frac{2}{3}\frac{\delta}{R_2}+\frac{\delta}{3R_3}\right) \quad (14)$$

At very high frequencies the inductance becomes equal to its limiting value

$$L_0=2\ln\frac{R_3}{R_2}. \quad (15)$$

The value of S is calculated from:

$$S=\frac{\Delta L}{L_0}=\frac{2\frac{1}{R_3}+\frac{1}{R_2}}{3\ln\frac{R_3}{R_2}}\delta=\frac{L_f-L_0}{L_0}. \tag{16}$$

The depth of current penetration $\delta$ in meters is calculated from the formula:

$$\delta=\frac{1}{\sqrt{\pi\mu\sigma}\,\sqrt{f}} \tag{17}$$

or for copper conducting surfaces at 20°C, in centimeters

$$\delta=\frac{6.62}{\sqrt{f}}, \tag{18}$$

where $f$ is the frequency in cps.

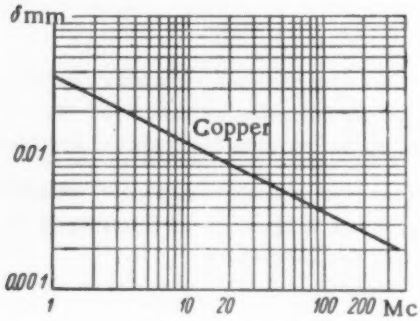


Fig. 5.

Figure 5 shows the values of $\delta$ for a type KVCh-2 capacitor made of copper of dimensions $R_3$ = 25 and $R_2$ = 23.2 mm [1].

Figure 3 shows the values of qS for a capacitor with $C_s$ equal to 500, 200 and 100 $\mu\mu$f.

The effect of temperature and frequency changes on the effective capacitance of coaxial capacitors. Let us examine the variations of the effective capacitance of a coaxial capacitor due to changes in frequency and temperature which affect the length of the capacitor, i.e., for

$$C=C_0\,l\,(1+\alpha\Delta t)\,(1+p), \tag{19}$$

$$dC=\frac{\partial C}{\partial t}\,dt+\frac{\partial C}{\partial\lambda}\,d\lambda. \tag{20}$$

Having substituted in this expression the partial derivatives of functions (20) it will assume the form:

$$\frac{dC}{C_s}=\alpha_t\,(1+p+N)\,dt-N\,\frac{d\lambda}{\lambda}. \tag{21}$$

It will be seen from the above that the capacitance temperature coefficient of a coaxial capacitor is

$$\text{TCE}=\alpha_t\,(1+p+N), \tag{22}$$

where $\alpha_t$ is the linear temperature coefficient of the metal of the capacitor electrodes.

The value of coefficient N is calculated from the series

$$N=26.318\left(\frac{l}{\lambda}\right)^2+831.23\left(\frac{l}{\lambda}\right)^4+19920.0\left(\frac{l}{\lambda}\right)^6+423000\left(\frac{l}{\lambda}\right)^8. \tag{23}$$

The relation $N=\psi(l/\lambda)$ is represented graphically in Fig. 2.

The capacitance temperature coefficient of the capacitor depends mainly on the variations of its length with temperature changes, since the impedance of the coaxial capacitor remains constant under these conditions.

The second term of (21) characterizes the relation of the capacitance to frequency.

The analysis of function $N = \psi(l/\lambda)$ shows that for $l/\lambda = 0.13$

$$\frac{dC}{C_s} = \frac{d\lambda}{\lambda}. \qquad (24)$$

The value of $l/\lambda = 0.13$ is critical, since for $l/\lambda < 0.13$ the effective capacitance depends but little on frequency variations and it is advisable to work in this region. For $l/\lambda > 0.13$ this relation rises rapidly thus leading to a greater error in the effective capacitance at higher frequencies.

In (19) it is possible to neglect the variations in $q$ and S due to temperature instability since these variations are very small.

The effects of other external phenomena, such as the instability of humidity, permittivity, and air pressure, on the effective capacitance of a type KVCh capacitor are similar to those encountered with the widely used low frequency capacitors. This question has been dealt with in detail in [1]. These effects in view of their smallness as compared with the basic errors can be neglected.

The basic error and the frequency range of coaxial capacitors. The error in the effective capacitance of a separate coaxial capacitor is determined by several frequency errors:

The error in low-frequency certified capacitors equal to 0.003-0.01%;

The error in determining the capacitance correction which may amount to 0.05-0.1% for $l/\lambda < 0.13$;

The error due to a partial disruption of the capacitor uniformity at its external end. This error depends on the value of the connector boundary field which is transferred to the open end of the capacitor when the latter is joined to the connector.

The capacitance formed by this field, when the former is transferred from the end of the capacitor to its input, will not be the same as at the open end of the connecting device which existed there before the capacitor was connected. The difference between these two boundary capacitances depends on the absolute value of the boundary capacitance and on the ratio $l/\lambda$ and may amount to 0.02-0.1 μμf.

The total error in producing the effective capacitance will be equal to 0.1% ± 0.1 μμf.

The value of this error, if required, can be decreased by a careful evaluation of the variations in the field when the capacitor is connected to the measuring equipment, but in this instance the capacitor should be considered as a coaxial line with a small capacitance connected to its open end.

D. Woods has arrived at similar conclusions in [2] where he states that the capacitance of a coaxial capacitor can be calculated at 200 Mc with an error of 0.1%. The formula derived by him for determining the effective capacitance contains a calculated value for $C_s$ and not a value measured at a low frequency as was done in our work.

## SUMMARY

The accuracy of determining the effective capacitance of coaxial cylindrical capacitors depends to a great extent on the construction of the connecting device of the instrument to which the capacitor has to be joined. The best junction device is the one which reproduces the construction of the coaxial capacitor. In this instance the error due to an edge field will be minimal and there will be no error at all due to the nonuniformity of the field.

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# IMPROVEMENTS IN THE TECHNIQUE OF MEASURING THE Q FACTOR OF A RESONATOR IN A CIRCUIT WITH A MEASURING LINE

G. Ya. Mirskii

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Among the various methods for determining the Q factor of resonators in the centimeter range, the method of measuring by means of the "half- power" point on the resonance curve of the resonator is well known and usually made by means of a measuring line circuit [1-6]. This method consists of the following.

The resonator under test serves as a terminating load of a circuit consisting of a klystron generator, a decoupling element (attenuator or ferrite rectifier), a measuring line and a device for measuring frequencies.

The frequency $f$ of the klystron generator is tunable in equal frequency intervals (of the order of several megacycles) by means of a frequency measuring device. For each frequency value $f_i$ the value of the voltage standing-wave ratio $k_i$ in the channel connecting the generator with the resonator is measured by means of a measuring line. From the data thus obtained a graph of the relation of the voltage standing-wave ratio to frequency $k = \psi(f)$ is plotted (Fig. 1). From this curve the value of the voltage standing-wave ratio at resonance ($k_0$) is determined, and from formula

$$k=a+\sqrt{a^2-1}\,, \tag{1}$$

where

$$a=k_0+\frac{1}{k_0}+1,$$

the value of the voltage standing-wave ratio $k_{1/2}$ which corresponds to the "half-power" level of the resonator's resonance curve is calculated. From the bandwidth $(2\Delta f)_{1/2}$ obtained at the "half-power" level and the value $f_0$ of the resonance frequency, the loaded Q factor of the resonator is calculated:

$$Q_e=\frac{f_0}{(2\Delta f)_{1/2}}. \tag{2}$$

The main defects of the above method consists in the amount of labor required for plotting curve $k = \psi(f)$, (the value of the voltage standing-wave ratio which is measured at 10-12 points) and in the distortion of the curve in its upper portion due to the errors in measuring large values of the standing-wave ratio , the contact losses, and to losses in the junction of the resonator with the channel.

The above defects can be decreased to a considerable extent if the Q factor of the resonator is determined at an arbitrary level $k_x$ instead of at the half-power level $K_{1/2}$; the former level being a little higher than the resonance value of the voltage standing-wave ratio $k_0$. This level is selected for each resonator in such a manner that only the lower part of the resonance curve for relatively small values of the voltage standing-wave ratio is plotted, and the bandwidth at the selected level is not too narrow.

In order to obtain a computing formula, let us use the expression which represents the relation of the Q factor of the resonator itself to the relative mistuning and the voltage standing-wave ratio (whose derivation can be found, for instance, in [6]):

$$Q_0=\frac{1}{\nu}\sqrt{\frac{(k-k_0)\,(kk_0-1)}{k}}. \tag{3}$$

For an arbitrary level $k_x$ (3) is written in the form

$$Q_0 = \frac{f_0}{(2\Delta f)_x}\sqrt{\frac{(k_x-k_0)(k_xk_0-1)}{k_x}}, \tag{4}$$

where $(2\Delta f)_x$ is the bandwidth measured at level $k_x$.

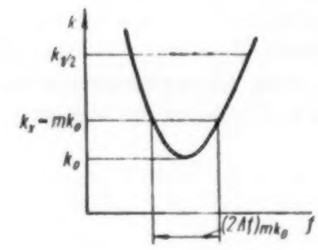


Fig. 1.

The calculations can be simplified considerably if the voltage standing-wave ratio $k_x$, at whose level the bandwidth is determined for substitution in (4), is expressed by means of $k_0$:

$$k_x = mk_0$$

where m is a value chosen for convenience and accuracy of measurements (Fig. 1).

If (5) is taken into account, formula (4) will assume the form:

$$Q_0 = \frac{f_0}{(2\Delta f)_{mk_0}}\sqrt{(m-1)\left(k_0^2-\frac{1}{m}\right)}. \tag{6}$$

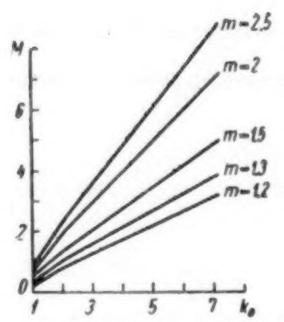


Fig. 2.

By introducing the notation

$$\sqrt{(m-1)\left(k_0^2-\frac{1}{m}\right)} = M, \tag{7}$$

we shall obtain in its final form the computing formula for calculating the Q factor of the resonator:

$$Q_0 = M\frac{f_0}{(2\Delta f)_{mk_0}}. \tag{8}$$

Since coefficient M is a function of two variables, those of $k_0$ and m, it is convenient to use for its determination a graph which is plotted beforehand (Fig. 2).

When the measurement of the Q factor of a resonator is based on (8) the measurement technique consists of the following. The frequency of the klystron generator is tuned in equal intervals by means of a frequency measuring device (a spectrum analyzer or a wavemeter with a high Q factor).

The value of the voltage standing-wave ratio is measured at 5-6 points in a region close to the resonance point of the resonator. From the values thus obtained a portion of the curve is plotted on millimetric paper in terms of coordinates k, $f$. At the level of $k_x = mk_0$ the bandwidth is determined $(2\Delta f)_{mk_0}$. The value of m is chosen so that on the one hand the level of $mk_0$ should not differ greatly from $k_0$, and on the other hand the bandwidth should not be too narrow (the problem of choosing m is dealt with below).

From the graph in Fig. 2 coefficient M, which corresponds to the voltage standing-wave ratio resonance $k_0$ and to the chosen value of m, is determined. The value of $Q_0$ is calculated from (8). The loaded $Q_l$ factor and the external $Q_e$ factor can be obtained by means of the well-known relations:

$$Q_e = \frac{Q_0}{k_0+1}\ ;\ Q_l = \frac{Q_0}{k_0}. \tag{9}$$

The level of $mk_0$ should be chosen so that the relative error in determining the bandwidth $\delta(2\Delta f)_m$ at that level should not exceed the relative error of bandwidth $\delta(2\Delta f)_{1/2}$ at the "half-power" level. The analysis of (4) leads to an expression for ratio $\frac{\delta(2\Delta f)_m}{\delta(2\Delta f)_{1/2}}$ (without taking into consideration any distortions in curve $k = \psi(f)$ in the region of high values of the voltage standing-wave ratio) given below:

$$\frac{\delta(2\Delta f)_m}{\delta(2\Delta f)_{1/2}} = \frac{\left(1-\frac{1}{m_{1/2}}\right)\left(k_0^2-\frac{1}{m_{1/2}}\right)}{\left(1-\frac{1}{m}\right)\left(k_0^2-\frac{1}{m}\right)} \cdot \frac{\delta k_m}{\delta k_{1/2}}. \tag{10}$$

where $k_m = mk_0$ is the voltage standing-wave ratio at the level $mk_0$; $k_{1/2} = m_{1/2}k_0$ is the voltage standing-wave ratio at the "half-power" level; $\delta k_m$ and $\delta k_{1/2}$ are respectively, the relative errors in measuring the voltage standing-wave ratio at the $mk_0$ and the "half-power" levels.

For $k_0 > 3$ expression (10) can be written in a simplified form:

$$\frac{\delta(2\Delta f)_m}{\delta(2\Delta f)_{1/2}} \simeq \frac{m_{1/2}-1}{m-1} \cdot \frac{m}{m_{1/2}} \cdot \frac{\delta k_m}{\delta k_{1/2}}. \tag{11}$$

Assuming that $\delta k_{1/2} = \alpha\frac{m_{1/2}}{m}\delta k_m$ (where $\alpha = 1.1$-$1.5$ when high values of the voltage standing-wave ratio are measured by the method of doubling the minimum, and $\alpha > 1.5$ when the "maximum-minimum" method is used) we obtain:

$$\frac{\delta(2\Delta f)_m}{\delta(2\Delta f)_{1/2}} \simeq \frac{m_{1/2}-1}{m-1} \cdot \frac{m^2}{\alpha m_{1/2}^2}. \tag{12}$$

Taking the limiting conditions $\delta(2\Delta f)_m \simeq \delta(2\Delta f)_{1/2}$, from (12) we obtain an equation for a tentative determination of the value of <u>m</u>:

$$m-1 = \frac{m^2}{b}, \tag{13}$$

where

$$b = \frac{\alpha m_{1/2}^2}{m_{1/2}-1}.$$

The calculations are referred to the following values: $m \approx 1.5$ for $k_0 = 3$ and $\alpha = 1.2$; $m = 1.3$ for $k_0 = 6$ and $\alpha \approx 1.4$.

Although according to the condition on the basis of which <u>m</u> was calculated the errors in measuring the Q factor at the level of $mk_0$ – $\delta Q_m$ and the "half-power" level $\delta Q_{1/2}$ are the same, experimental data shows that $\delta Q_m < \delta Q_{1/2}$. This is due to the fact that at the level of $mk_0$ there is practically no distortion of the curve $k = \psi(f)$ which is noticeable at large values of the voltage standing-wave ratio.

The measurements are considerably speeded up if a directional coupler with a detector head (adjusted to the reflected wave) and an oscilloscope are included in the circuit for determining the resonant frequency, and if the scanning voltage of the oscilloscope is used for wobbling the klystron frequency (Fig. 3).

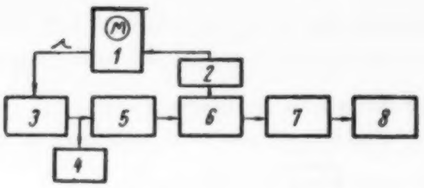


Fig. 3. 1) Oscilloscope; 2) detector head; 3) klystron generator; 4) spectrum analyzer or wave meter; 5) decoupling element; 6) directional coupler; 7) measuring line; 8) resonator under test.

The above technique of measuring the Q factor has been tested in several wavebands and is used in laboratory testing. The duration of such measurement is 1/2 to 1/3 of that required for the "half-power" method of determining the Q factor, and its accuracy is 1.5 to 2 times higher.

The possibility of using standard apparatus for measuring the Q factor of resonators makes it convenient to use the above method despite the availability of new, high-speed instruments for measuring the Q factor. This method is especially convenient for working in new frequency bands for which new high-speed measuring apparatus would have to be constructed at a considerable expenditure of time and money.

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# A DEVICE FOR MEASURING FREQUENCIES

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For the measurement of the frequency of electromagnetic oscillations it is possible to use a method based on the measurement of a period of these oscillations. This method provides a relatively simple measurement of frequency with a sufficient degree of accuracy over a wide frequency band, for the purpose of which the duration of a large number of periods is measured and then the duration of one period and the frequency is determined. The number of periods can be counted by means of trigger dividers similar to those used in electronic computers.

The frequency at the input of the dividers will be $2^n$ times higher than that at the output, taking $n$ to mean the number of dividers. Hence if the period of oscillation is measured at the output, which can be made accurately for a required duration of the period (the number of dividers used), it will not be difficult to determine the period and frequency at the input of the device, i.e., the required period and frequency of oscillations.

$$\tau = \frac{T}{2^n}; \quad f = \frac{2^n}{T}. \tag{1}$$

where $\tau$ and $f$ are the period and frequency of the signal under test; T is the period of the signal at the divider output.

The block schematic of this device is shown in Fig. 1. The basic element of this circuit consists of a frequency divider which uses a double triode 6N8 (Fig. 2). The trigger is controlled through a differentiating RC circuit (50 kilohms, 510 $\mu\mu$f) and two germanium detectors type DGTs-4.

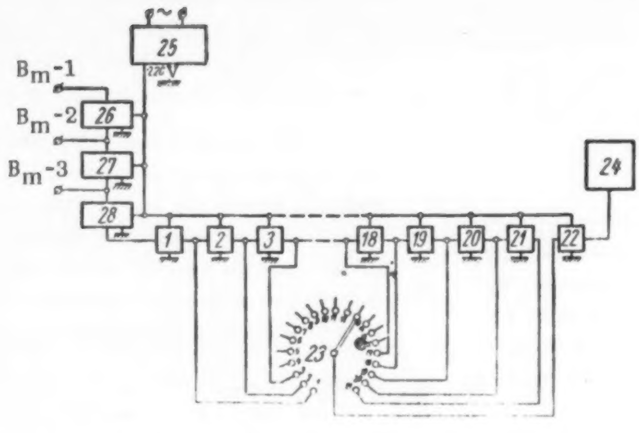


Fig. 1. 1, 2, 3. . . 21) are the intermediate frequency dividers; 22) output frequency divider; 23) switching panel; 24) timer; 25) power pack; 26, 27) input amplifiers; 28) output converter.

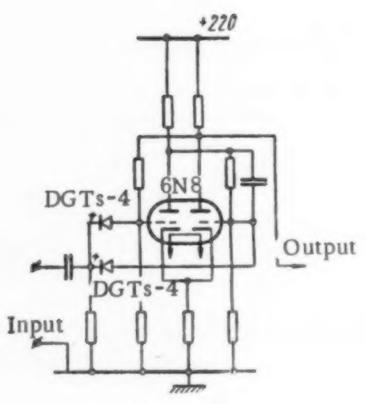


Fig. 2.

The trigger parameters have been chosen in such a manner that the deviation of any of them by 20-30% does not interfere with their work. All the frequency dividers (except the last one) are identical. The output of each divider is connected to a switching panel 23 (Fig. 1),the input of the last divider 22 is connected to the same panel in such a manner that it can be switched to any of the intermediate dividers between 1 and 21. Thus it becomes possible to vary the number of dividers between 2 and 22. This provides the possibility of dividing the input frequency by a factor up to $2^{22} = 4194304$.

The output trigger differs from the intermediate ones by the fact that its anode circuits are connected to the windings of a polarized relay type RP-4, which is intended for controlling the timer. The windings of the relay are connected to different anodes in such a manner that the fluxes of the magnetic circuits are in opposition. The changing over of the divider from one stable position to the other operates the relay, transferring its contacts from one side to the other. Thus the timer will measure the duration of half the period of oscillations at the output of the last divider (or the duration of a full period of the preceding divider).

In addition to the polarized relay, the output divider circuit includes a neon signalling lamp MN-5 intended for a tentative determination of the frequency by means of a pocket stopwatch, and a switch by means of which the divider can be reset to zero and thus prepared for a subsequent operation.

In order to ensure an efficient and reliable operation of the divider, rectangular pulses with sharp fronts should be fed to the input. The shape of the measured voltage, however, may vary (it is usually sinusoidal). In order to convert the input voltage to a rectangular shape a trigger converter is included in the circuit for the purpose of shaping rectangular pulses of the same frequency as the frequency under test. The trigger will operate normally if the voltage of the controlling signal is in the range of 10-250 v. For the purpose of measuring weak signals a two-stage amplifier using 6Zh8 type pentodes is provided. If one stage only is used input voltages between 1.0 and 15 v can be measured,for two stages the voltages are 0.05 to 2 v.

The frequency characteristic of the input amplifiers provides the required voltage gain in the range of 20 to 20,000 cps without any appreciable distortions of the signal. The converting trigger can operate in the range of 0 to 20,000 cps.

For measurements of time a mechanical or electrical timer can be used. The latter requires a frequency-stabilized supply.

The circuit is simple in adjustment. It consists of checking and adjusting anode voltages and checking the adjustment of the trigger frequency dividers.

The measurement error obtained by means of the above equipment depends mainly on the variations in the lag of switching the timer in and out. These errors have opposite signs and to a certain extent cancel each other.

Let us assume that the difference in the lag between the switching in and out of the timer amounts to $\Delta t$. The relative measurement error will then amount to

$$\gamma_r = \frac{\Delta t f}{2^n}. \tag{2}$$

It follows from the above that for a given $\Delta t$ the relative error will decrease with the measured frequency and a rising number of dividing stages. If we assume that $\Delta t = 0.04$ sec the relative error of measurement $\gamma_r \approx$ $\approx 4 \cdot 10^{-4}$ when the frequency is of the order of 20 kc and $n = 21$.

## SUMMARY

The above method of measurement is of interest in connection with its application in the audio-frequency range. Its use is most expedient with mechanical timers.

# PHYSICOCHEMICAL MEASUREMENTS

## MEASURES FOR DEVELOPING THE WORK IN THE SPHERE OF pH MEASUREMENTS

I. Ya.

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The indication of the hydrogen ion activity (value of pH) is one of the principal means of registering the technological developments and the quality of many industrial processes.

Instruments for the automatic checking or control of pH are or can become the basis for group automation of many technological processes of national importance in several industries such as the chemical, chemicopharmaceutical, oil processing, metallurgical, food, textile, and other industries. The value of pH is one of the most important indicators in scientific and experimental investigations in modern medicine, biology, biochemistry, and agriculture.

Thus the development of scientific investigation work in the sphere of pH measurements and the development of instruments for measuring and controlling the value of pH (pH-meters) is of great importance for our national economy.

A number of special conferences was devoted to furthering the work in the sphere of pH measurements, including conferences in the Committee of Standards, Measures and Measuring Instruments. At the end of 1959 a conference on pH measurements was organized in Tiflis by the State Scientific and Technical Committee (GNTK) of the Council of Ministers of the Georgian SSR, the Council of the Scientific and Technical Society (NTO) and Georgia and the Georgian Republican Administration of the Scientific and Technical Society of the instrument-making industry. The conference was attended by 250 representatives from a majority of Union Republics and in fact, it was an All-Union Conference on pH measurements.

Below we give a brief review of the conditions and the required measures for the further developmen. of work in the sphere of pH measurements, on the basis of the materials of the above conferences.

Scientific-research work. Scientific investigation in the sphere of the theory and practice of pH measurements is widely developed in several large scientific organizations, higher teaching establishments, design offices and laboratories.

The theory of the glass electrode, developed by professor B. P. Nikol'skii of the Leningrad State University (LGU), has received general recognition. The experimental work carried out in recent years has confirmed the most important theses of this theory.

The work carried out in the Khar'kov and Leningrad State Universities, the Leningrad Technical Institute (LTI) and the Karpov Physicotechnical Institute (FKhI) on the thermodynamics of the physicochemical processes taking place in water and other solutions are of great importance in establishing the concept of the acidity of a solution and for standardizing the pH scale.

The work on the acidity of nonaqueous solutions carried out in the Khar'kov State University (KhGU) by Prof. N. A. Izmailov and other scientific collaborators made it possible to establish a unified acidity scale for several alcohols (propanol, butanol, etc), and for a mixture of methanol and ethanol with water as well as a unit of acidity for other solvents (methanol, ethanol, formic acid, ammonia), which has a great practical significance in view of the wide use of nonaqueous solvents and their mixtures in laboratory and production practice.

As the result of studying the effect of the composition of glass on its electrode properties, electrical conductivity, chemical stability, density, its technological properties (crystallization, expansion coefficient, fusibility) and the experimental work carried out in this connection in the LGU, LTI, the Central Automation Laboratory (TsLA) of the Building Ministry of the RSFSR, the State Institute of Glass, FKhI, the Special Design Office (SKB) of PSA and other organizations, the composition of electrode glass was improved thus providing glass electrodes which can measure efficiently pH over a wide range (from 1 to 14 pH) up to +100°C, and pressures up to 5 kg-wt/cm$^2$. Various types of such electrodes have been made to satisfy industrial requirements.

The four grades of glass electrodes type 5079 (according to the composition of the glass) UNT, UST, KST and ShchVT developed by the TsLA of the Building Ministry of the RSFSR provide pH measurements at normal pressure and temperatures from +5 to +100°C, i.e., covering the majority of pH measurements encountered in industry, and in addition, these electrodes are simple in construction. As the result of State tests these electrodes have been approved by the Committee of Standards, Measures and Measuring Instruments for production and marketing. Electrodes made of glass No. 106 (LGU-LTI) and No. 25 (SKB PSA) are successfully used in industry.

Measurements of pH at high pressures and in certain special cases can be made by means of electrodes type L12-04 with a rubber packing, L14-02 and L14-03 with a ball and socket packing developed by the GSOKB.

The electrolytic switch developed by the SKB PSA in the shape of a microscopic hole has made it possible, owing to the simplificity of its design and ease of construction, to manufacture miniature combined electrodes, which are especially convenient for use in portable instruments; in particular, in instruments for measuring values of pH in soil and in bar pH-meters. These electrodes as well as electrodes with microslides have passed State tests and are recommended for general use.

The investigations carried out by the LGU on diaphragm electrodes made of ion-exchange resins made it possible to measure pH values in concentrated acid solutions and fluorine media.

The investigations and experimental work carried out by the Ural Chemical Scientific Research Institute (UNIKhIM) and the All-Union Chemicopharmaceutical Scientific Research Institute (VNIKhFI) have established the possibility of using in a number of cases metal oxide electrodes for measuring pH. In particular it was shown at the UNIKhIM that tungsten electrodes can be used for measuring pH values in solutions containing fluorine ions at temperatures up to 90°C. The great hardness of tungsten makes it possible to use these electrodes for measuring pH in certain pulps with abrasive properties.

This brief list shows that the theoretical and experimental work of Soviet scientists has provided the possibility for a wide application of pH-meters in the most diverse spheres of science and technology.

Side by side with these achievements however there are many defects in the scientific research and design work in the sphere of pH measurements, the most outstanding of which is the lack of coordination in this work. Scientific investigation and the design of instruments are carried out by organizations of various departments and, as a rule, without any coordination, mutual agreement, or mutual information.

It is in the interest of our national economy to continue the theoretical work for a more exact scientific determination of the value of pH, and the development of scientific investigations with the object of satisfying the most diverse modern practical requirements.

It is necessary to investigate:

a) the thermodynamic properties of solutions with the aim of standardizing the pH scale which would provide unified and precise measurements in aqueous and nonaqueous solutions both under normal and high temperatures and pressures;

b) the possibility of measuring pH values at high (over 100°C) and low (below 0°C) temperatures and high pressures, as well as in especially corrosive media;

c) the possibility of obtaining new electrode glass, optimal in its over-all properties and develop the technology of manufacturing electrodes from it;

d) the possibility of developing other types of electrodes such as metal oxide, diaphragm, oxygen, etc;

e) the properties of electrodes by comparing various systems with previously developed new types of electrodes.

The successful fulfilment of these tasks can only be accomplished with due coordination of the scientific research and design work.

The Tiflis conference on pH measurements recommended the establishment of a scientific technical council attached to the SKB PSA with the participation in its work by representatives from LGU, KhGU, LTI, the Leningrad Technological Institute of the Paper Industry, the FKhI, the Novocherkassk Hydrochemical Institute of the Acad. Sci. USSR, The Glass Institute, the Institute of Pure Reagents, the Moscow and Khar'kov Chemicopharmaceutical Institutes, the TsLA and other organizations.

Development and design work. Several scientific research and design organizations have produced laboratory and commercial type of pH-meters and transducers.

The "Moskip" factory and the Central Design Office of the "Pishchemashpribor" Plant, which have worked in this sphere over 25 years, produced the first Soviet laboratory instruments of this kind (P-4, P-6, LP-5). These plants have now developed new instruments of a laboratory type LP-57 with a high sensitivity (0.005 pH), LP-58, LP-59 (for measuring pH values of soil),and also commercial type pH-meters AP-5 and APR-5 for automatic control and checking of production in the food processing industry.

The TsLA has developed several types of commercial pH-meters.

A unit type pH-meter with a transducer PVU-5256 can work, in conjunction with any remote recording or controlling device with a range of 0 to 5 ma and 0 to 50 mv (for instance ÉPP-09). The instrument is designed in such a way that it is possible by means of external controls to set any nominal measuring band for pH values over the entire measuring range (0 to 14 units); the instrument provides temperature compensation for the measured emf in the range of 0 to 100°C. As the result of State tests carried out in July and August 1959 the instrument has been recommended for mass production.

A universal pH-meter with several scales which provide pH measurements over the whole range (0 to 14 units) including highly acidic solutions; an electronic high resistance potentiometer type PPV-5078 with a disk chart is used in this instrument for recording purposes.

A high precision pH-meter with an error of measurement not exceeding ±0.03 pH and other types of instruments has been developed.

The TsLA has also developed several modified transducers for measuring pH under varying conditions including flow, immersion and floating transducers.

The SKB PSA, one of whose main occupations is the development of pH-meters, has designed several portable types of pH-meters and transducers for commercial use including the following:

a miniature portable rod instrument type PShP-58 for periodic measurements of pH values under production conditions which provide direct measurements in the range of 2 to 12 units for commercial quantities and temperatures between 5 and 65°C;

a portable type PPP-58 and a laboratory type PLP-58 meters for measuring pH values in soil with a range of 3 to 10 units; these instruments have passed State tests and have been approved;

a transducer type DPPV-58 for measuring, recording and controlling pH values in the boiler water supply with a range of 3 to 11 units at temperatures of 5 to 95°C.

The GSOKB has developed several pH-meters and transducers for commercial use. It should be noted, however, that the recording instruments (ÉPP-26, ÉPP-28, ÉPP-29, and PSV-1) used in conjunction with some of these meters have, according to State tests, important defects and by the decision of the Committee of Standards, Measures and Measuring Instruments must be redesigned.

Transducers type DKI and transducers made up of elements ÉI and ÉS have several design and operational defects which must be eliminated.

The UNIKhIM has developed a laboratory pH-meter type LLPU-2 with a transducer D-54 with a range of 1 to 10 units, and a possibility of using this instrument for potentiometric titration; the Institute has also developed another type of pH-meter (LPU-4) and several transducers.

The Scientific Research Institute of Organic Semifinished Materials and Dies (NIOPIK) has developed miniature transducers with the electrode placed in an isopotential plane; it has also developed an equipment for measuring the pH of film-forming media.

A laboratory pH-meter type VIZP-6 for determining the acidity of soils has been developed by the All-Union Scientific Research Institute for the protection of plants.

Laboratory and commercial type pH-meters have also been developed by the SKB ANN.

Other organizations have developed pH-meters mainly in order to satisfy their own requirements and in some instances owing to the difficulty of obtaining commercial type instruments.

The majority of the above organizations develop pH-meters in order to satisfy the requirements of certain industries which they serve; thus for instance, the TsLA has developed a pH-meter mainly for use in the metallurgical industry and special production, the TsKB of the "Pishchemashpribor" plant and the "Moskip" factory (in their commercial instruments department) have developed meters for the food processing industry and the UNIKhIM and NIOPIK for certain branches of the chemical industry, etc.

The design and production of pH-meters are not the main activity of these organizations and are conducted by them side by side with the development of many other instruments, and in some instances their work is even of a casual nature. For this reason, very often the work is conducted haphazardly without mutual information and obviously without coordination of basic research. As a result of it many of the instruments thus designed are not at the level of modern technique.

However, it will be seen from the above that despite the defects in the organization of development and design work several types of transducers, pH-meters, and complex instruments both for commercial and laboratory purposes have been developed according to modern requirements for checking and controlling pH values under various production and laboratory conditions. A number of instruments has passed State tests with satisfactory results. Thus we have all the prerequisites for the development of mass production of pH-meters.

In order to satisfy completely the requirements of our national economy with respect to control instruments and means of automation, it is necessary to adopt several urgent measures.

1. To work out general requirements for electrodes, transducers, auxiliary instruments and pH measuring sets, keeping in mind the necessity of making a standard series of instruments with a unified scale of pH values, unified output signals from transducers and also keeping in mind the necessity to provide coupling to other control, automation, and recording systems.

It is important that the required accuracy of the commercial instruments be properly estimated. The tendency of people placing orders for commercial instruments is to exaggerate the required accuracy, thus often leading to an unjustifiable complication in the construction of the instruments which produces difficulties in their manufacturing and operation, and considerably raises their costs. Prof. B. P. Nikol'skii (LGU) has shown by appropriate calculations that for many technological processes measurements of 0.2 and even 0.3 pH accuracy are completely satisfactory; only for certain processes, for instance, in separating rare earth metals is it necessary to have an accuracy of measurements of 0.02-0.01 pH. Thus instruments of third-grade of accuracy are required:

a) commercial instruments with a measurement error not exceeding ±0.2 pH;

b) precision instruments for accurate investigations with an error of the order of ±0.01 pH;

c) intermediate instruments with an accuracy between the first and second group for control and industrial laboratory purposes.

2. To establish such a production method that only pH-meters of general commercial designation, which can be used with any transducer and any registering instrument, shall be recommended for mass production.

3. To unify, as far as possible, units and components of transducers and pH-meters, and develop the required standards and specifications.

4. To provide a higher stability and reliability in operation and improved operational properties of commercial instruments taking into consideration their use in industrial establishments. The development of experimental samples should be considered completed only if they have successfully passed field tests under the most difficult production conditions for which they are designed.

5. To develop a program for State testing of pH-meters, including the checking of electrodes, transducers, converters, auxiliary instruments, which provides a most complete and exhaustive evaluation of the technical, operational and metrological properties of the instruments.

6. To develop commercial instruments for checking and controlling pH values in production over a wide range of temperatures (from $-10°$ to $+150°C$) and pressures (up to 250 kg-wt/cm$^2$) in corrosive and nonaqueous media.

7. To develop a universal titrometer with automatic potentiometric titration.

8. To extend the 1960/61 scope of investigations and design of pH-meters, in the first place in the SKB PSA and also in other organizations which are working successfully in this sphere (TsLA, TsKB of "Pishchemashpribor" and the "Moskip" plant, etc.)

9. To coordinate the activity of scientific-research and experimental-design establishments working in the sphere of pH measurements by means of the aforementioned scientific and technical council thus obviating any duplication of work. Similar coordination should be provided in developing experimental designs of auxiliary instruments for pH-meters with the object of establishing a series of standard instruments.

Commercial production of pH-meters. Despite the successes achieved in the scientific-research and experimental-design work, the industrial production of pH-meters on a required scale has not yet been achieved. The design organizations which are developing these instruments are therefore obliged to produce small batches of pH-meters, transducers, and electrodes in order to satisfy, if only in part, the requirements of our industry. Such an organization not only hinders the development of mass production but also limits the possibility of new development, whereas the requirement in pH-meters and glass electrodes is, according to the available data, very large and there is no doubt that the development of production automation and the mastering of new production processes will greatly increase this demand.

The development of the mass production of pH-meters is at present greatly hindered by lack of commercial production of special glass electrodes and electrode glass, which has not yet been organized. This circumstance forces the plants which produce pH-meters to make their own glass and manufacture electrodes, thus raising their cost without ensuring stable characteristics and interchangeability of electrodes.

Great difficulties in developing new designs and mass-producing pH-meters are caused by the lack of catalogs of details which are produced by the electrical and radio industries and are required in pH-meters, for instance, electrometer tubes with a high input resistance and a grid current of the order of $10^{-15}$ amp, miniature highly-sensitive microammeters, potentiometers which have input parameters suitable for pH-meters, instruments for measuring the emf of circuits with a high internal impedance (of the order of hundreds of megohms), miniature supply sources (storage batteries and batteries) etc. Difficulties are also experienced owing to the lack of the required plastic constructional materials which remain stable in corrosive media (acid and alkali) at temperatures up to $+150°C$.

In order to satisfy the requirements of our national economy in pH-meters it is necessary to:

a) start mass production and raise the production of commercial pH-meters (transducers PVU-5256) as soon as possible, as well as of portable and laboratory pH-meters, and organize new specialized establishments for mass production of pH-meters and oxidation media meters as well as transducers of various types for the above instruments;

b) organize the production of special electrode and throttle glass, as well as glass electrodes with stable characteristics, calomel electrodes and other glass products used in pH-meters in quantities which would satisfy industrial requirements;

c) extend the production of automatic electronic potentiometers including those designed for use with 6-12 pH-transducers and higher.

d) organize mass production of the above electrical and radio components, plastic materials, as well as choppers for auxiliary amplifiers.

Metrological work and standardization in the sphere of pH measurements. Important scientific research work in developing the foundations for standardizing pH measurements was carried out in the KhGU (V. V.

Aleksandrov). The standardization of the calibration of glass electrodes was carried out by a Commission organized by the State Planning Committee and the State Scientific and Technical Committee of the USSR, but its work was not completed. The All-Union Scientific Research Institute of Metrology has not completed the development of the equipment and instructions for testing pH-meters. As a result of these circumstances the metrological bases of pH measurements has not yet been developed.

There does not exist a single legalized scale for a pH value, as a result of which various organizations use different systems for calibrating the electrode parameters and various methods for their testing, thus preventing a unification of measurements.

Neither does there exist a unified system of calibrating the emf of electrode systems with glass electrodes, thus making the use of auxiliary instruments or transducers impossible in conjunction with these electrode systems if the former are made by different organizations. A table of normal buffer solutions for reference use in checking and graduation systems for electrodes has not yet been developed.

Techniques for determining pH in various branches of our national economy have not yet been developed, for instance, in agriculture, medicine, biology, etc. Owing to the lack of recognized techniques for measuring, for instance, pH values of soil, measurements are made both in aqueous and saline suspensions as well as with different electrode systems. The results of such measurements are obviously difficult to compare.

The lack of established metrological standards in the sphere of pH measurements as well as instructions for checking pH-meters and reference-checking equipment hinders the development of instrument making in this sphere and makes it difficult to use these instruments owing to the lack of reliable means of checking them.

In order to bring up to date metrological work in the sphere of pH measurements meeting the requirements of our national economy, it is necessary:

1. To develop a calibration system for electrodes; a specification for calibrating the emf of electrode systems with glass electrodes; specifications and requirements for a reference, saturated, calomel electrode; a table of normal buffer solutions, a specification for them and a numerical value for pH for use as a reference for checking and calibrating electrodes. At the same time it is necessary to work out requirements for preparations necessary in making up normal buffer solutions.

2. To organize the production of preparations for making normal buffer solutions in quantities satisfying the requirements of factories and other organizations, for checking and calibrating pH-meters, and to produce a series of secondary normal buffer solutions for the purpose of supplying them to various organizations.

3. To develop reference equipment for checking instruments which measure the value of pH; a test circuit for measuring the value of pH; instructions for checking instruments used in measuring the value of pH including those used at high temperatures and a technique for testing electrodes.

4. To provide State inspection of the production and use of instruments and an appropriate metrological servicing in this sphere of measurements.

The above metrological problems in the sphere of pH measurements require an urgent solution. It should be remembered however, that such a large amount of work and wide extent of problems connected with the solution of this question cannot be undertaken by metrological institutes alone. A successful solution is only possible if a wide cooperation of scientific-research organizations, design offices and industrial establishments is obtained. This work should be carried out under the guidance of the principal metrological institute, the D. I. Mendeleev All-Union Scientific Research Institute of Metrology.

# BASIC TENDENCIES IN THE DEVELOPMENT OF DIMENSIONAL CONTROL IN ENGINEERING ABROAD

M. I. Mekler

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A correct selection of the equipment and organization of control operations in industry has a direct effect on the quality and cost of production; and an increased volume of production, development of the conveyor belt system, and the related problem of mechanization and automation of production require a more productive and effective control of operations.

Although conveyor belt production deals with separate components, in its nature it approaches continuous processes, such as chemical and metallurgical production, and therefore methods used in its control have to be reorganized on similar lines: passing from the control of separate items to a process control. Although with this new type of control the same production is being checked, there exists a very important theoretical difference between the two types of control.

The control of separate products, which is made in order to ascertain whether they are within the set tolerances and to prevent rejects reaching the customer or being passed for further processing or assembly, can be carried out by a worker or inspector immediately after its manufacture or after the completion of a whole batch of products, by means of measuring instruments or limit gauges. The product is passed if its dimensions are within the prescribed tolerances, irrespective of the actual value of these dimensions within the set limits. The checking of the production process, especially in conveyor belt or automatic production, must be carried out continuously, i.e., in such a manner as to be able to determine at any moment that the process has not been disrupted. Measurements in this case become a means of determining the stability of the process and a source of information on whose basis the process can be controlled. In controlling the process it no longer becomes irrelevant by whom, when, and how the dimensions of the details have been measured. The measurements should be made either during production or immediately after machining at the bench, always by means of an indicating instrument in order to know the exact value of the dimensions under consideration at that moment. This provides the possibility of discovering in time the displacement of the mean value of the dimensions and make the required readjustment of the equipment. In this connection there has arisen an extensive development of various active means of measurement, not only of instruments for controlling during production, but also of all types of measurements directly connected with production thus permitting an immediate control of the production process by means of automatic or manual regulation.

A direct connection between production and control is reflected by the incorporation of measuring instruments in lathes; by the installation of controlling automatic devices directly in production lines and their use for readjusting machinery.

The automatic control system of the Sheffield Company can serve as an example of such a method; since it controls and sorts out products which are fed from 20 machines, and it transmits commands for readjustments of of the required machines on the basis of the measurement of the products.

In production control instruments where it is required to have accurate spacing, a minimum of measuring devices and the largest possible scales in order to facilitate their reading and raise accuracy, pneumatic and high-frequency capacitative methods have become widespread, especially for an automatic provision of accurate

gaps in matching details. The method consists in making one of the details (usually the bushing) accurately and then machining the fitting detail on a lathe with a simultaneous measurement of both details and an automatic stopping of the lathe when the two dimensions become balanced in an electronic circuit and the difference between them correspond to the set gap. Such instruments are produced in several countries (EAM, Movomatic, Marposs, and others).

Active checking and its use for controlling production is expressed not only in the development of the control equipment used directly in production for the required readjustments, but also in the replacement of limiting gauges by indicating instruments supplied with large and clear scales or signalling devices, which make the instruments suitable for use in workshops. In nonautomatic production there is a tendency to use mechanized multidimensional instruments, control devices,and precision scale instruments which are mounted directly at the work benches.

Control devices consisting of standard units are now being used in all countries.

Increasing requirements with respect to accuracy make it necessary to use instruments measuring in microns and fractions of microns in an increasing number of instances,not only in laboratories but also in workshops.

In order to improve the quality of the measuring equipment and extend its life,armouring by means of hard alloys is now extensively used, and gauges are being made from hard alloys,and base plates from hard rock. Another basic development is the dropping of the 100% check of the shape of details.

In the transition from the old pre-war methods of production to the modern highly productive conveyor method there developed a gap between the productivity of production and checking. This led to the omission of the 100% check and the adoption of sampling methods. Despite this however, many inspectors are still being employed in the engineering industry and their number may even increase due to the spreading of automation if the control methods are not changed.

A simple automation of the existing control operations, however, cannot provide an optimum solution of this problem, since the quality is ensured by the production method and not the inspector. If the controlled parameters in a given day are analyzed it will be found that at least one half of the checking consists of systematic errors due to an insufficiently high quality of production or an unsatusfactory condition of the equipment. Such parameters should be checked periodically by sampling methods as it is done,for instance,in the bearings and automobile industries in the USA, where by avoiding 100% inspection of the geometrical shape the productivity of the control automatic devices for bearing races, pistons and other details has been greatly increased.

## A DEVICE FOR IMPROVING THE BALANCING OF AC BRIDGES

Translated from Izmeritel'naya Tekhnika, No. 6, pp. 56-59, June, 1960

In universal ac bridges for measuring inductance the Maxwell circuit is widely used (Fig. 1).

When the bridge is balanced the inductance and Q factor of the measured coil is determined as

$$L_X = R_N R_A C_T , \tag{1}$$

$$Q_X = \omega R_T C_T \cdot \tag{2}$$

thus the bridge provides an independent reading of the inductance and Q factor: the inductance is read by means of the resistance dial $R_N$, and the Q factor on the resistance dial $R_T$. This constitutes a great advantage of the Maxwell bridge; its defect consists in a pronounced flat balancing at low values of the Q factor, which not only increases the time required for balancing, but also may under certain conditions lead to erroneous results.

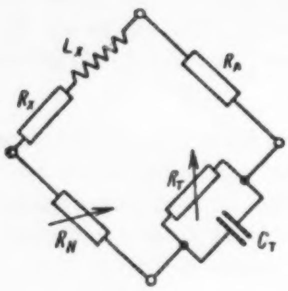

Fig. 1. $L_X$ and $R_X$ are the parameters of the coil under test; $R_A$ is the standard resistance; $C_T$ is the standard capacitance; $R_T$ and $R_N$ are the variable resistances by means of which the bridge is balanced.

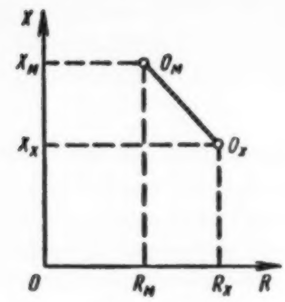


Fig. 2.

The voltage across the measuring diagonal of this bridge, expressed in fractions of the supply voltage, can be represented by:

$$\frac{E_0}{E_1} = \frac{R_X + j\omega L_X - \left(\dfrac{R_V R_A}{R_T} + j\omega R_N R_A C_T\right)}{A}. \quad (3)$$

Denominator A represents a complex expression, however, when the bridge is near to the balanced condition, it can be assumed constant and omitted from further consideration.

Voltage $E_0$ is proportional to the difference between the measured impedance $Z_X = R_X + j\omega L_X$ and impedance $Z_M = \frac{R_N R_A}{R_T} + j\omega R_N R_A C_T$, and is a function of the bridge parameters. Each one of these impedances can be represented by a point on a complex plane (Fig. 2). If impedance $Z_X$ is represented by point $O_X$ ($R_X$, $X_X$) and impedance $Z_M$ by point $O_M$ ($R_M$, $X_M$), voltage $E_0$ will be proportional to the distance between these points. Figure 3 shows the locus of impedance $Z_M$ for varying values of resistances $R_T$ and $R_N$. When resistance $R_T$ is changed only the real part of impedance $Z_M$ is affected, its imaginary part remains unchanged, hence the locus which represents impedance $Z_M$ in terms of the coordinates X-R will consist of a series of straight lines parallel to the R axis. The distance of these lines to the R axis is equal to the imaginary part of impedance $Z_M$. When resistance $R_N$ is changed both the real and imaginary parts of impedance $Z_M$ are affected; their ratio however, remains constant. Hence the locus of impedance $Z_M$ in terms of coordinates X-R is represented by a series of straight lines passing through the origin of the coordinates. The tangent of the slope angle with respect to the R axis is equal to $\omega CR_T$.

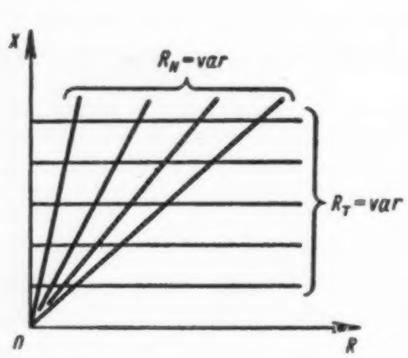


Fig. 3.

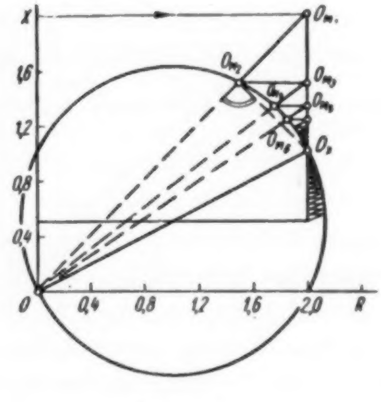


Fig. 4.

Figure 4 shows the balancing process of a Maxwell bridge. It has been assumed here that the Q factor of the coil is $Q_X = 0.5$ ($X_X = 1$, $R_X = 2$), i.e., the measured impedance is described in Fig. 4 by point $O_X$. Let the balancing be started at a setting of resistance $R_N$ when the imaginary part of impedance $Z_M$ is equal to $X = 2$ and the first balancing is carried out by means of resistance $R_T$. Then the point which characterizes impedance $Z_M$ will be displaced during balancing along a straight line parallel to the R axis. At point $O_{M1}$ the balancing will stop, since at that point the distance between points $O_M$ and $O_X$ will be at a minimum. If the balancing is continued by means of resistance $R_N$ the point characterizing impedance $Z_M$ will be displaced along the straight line $OO_M$, which passes through the origin of the coordinates. The balancing by means of resistance $R_N$ will stop at point $O_{M2}$ at which length $O_XO_{M2}$ is perpendicular to line $OO_{M1}$. Further balancing by means of resistance $R_T$ will displace the point which represents the measured impedance to $O_{M3}$, next, by balancing with resistance $R_N$ it will be moved to $O_{M4}$, etc., until the point characterizing impedance $Z_M$ coincides with point $O_X$. The locus of points $O_{M2}$, $O_{M4}$, $O_{M6}$, etc. which are obtained after balancing the bridge by means of resistance $R_N$ is a circle whose diameter consists of length $OO_X$. It will be seen from Fig. 4 that for small values of $Q_X$ a large number of consecutive balancing operations are required to balance the bridge. It is especially pronounced in the case when the imaginary part of impedance $Z_M$ is smaller than the real part of impedance $Z_X$. As an example of such an instance Figure 4 shows the process of balancing the bridge from the same value of $Q_X = 0.5$ but starting the balancing with $X = 0.5$.

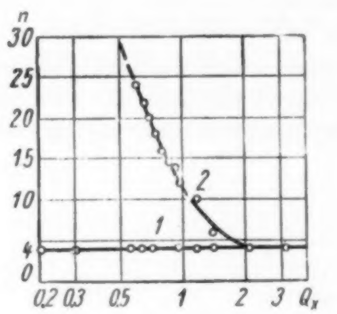


Fig. 5.

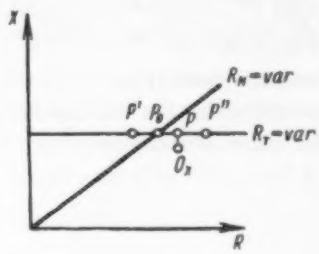


Fig. 6.

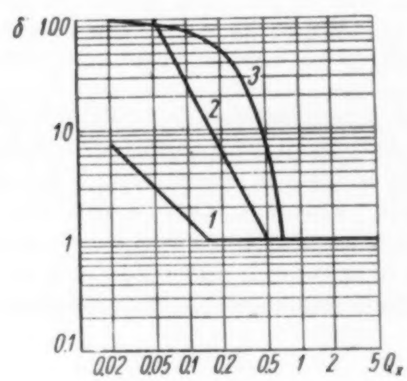


Fig. 7.

In order to eliminate this important defect of the Maxwell bridge the General Radio Company has applied [1, 2] in their bridges, type 1650-A, a special device called "Ortonull." By means of the "Ortonull" it becomes possible to vary the imaginary component of impedance $Z_M$ without affecting its real component. Moreover the loci characterizing impedance $Z_M$ in terms of X−R coordinates will be straight lines parallel to the X axis when resistance $R_N$ is varied, that is, perpendicular to the straight lines which characterize impedance $Z_M$ for a varying resistance $R_T$. Thus the best convergence of the bridge is obtained with a minimum number of operations. For this purpose a mechanical friction drive is introduced between the slides of resistors $R_N$ and $R_T$. The slide of the $R_T$ resistor has a low friction, whereas that of resistor $R_N$ has a large friction. The relation between the frictions of these two slides is selected in such a manner that when the slide of resistor $R_N$ is rotated the slide of resistor $R_T$ also turns, but when the slide of $R_T$ is rotated that of $R_N$ remains stationary. Thus when the slide of $R_N$ is rotated a constant difference in the angle of rotation of slides $R_T$ and $R_N$ is maintained. Resistors $R_N$ and $R_T$ are wire wound and their value is related exponentially to the angle of rotation of their slides, i.e.:

$$R_T = K_T e^{-\alpha_T}, \tag{4}$$

$$R_N = K_N e^{-\alpha_N} \tag{5}$$

Under such conditions the ratio of the resistances comprising the real component of impedance $Z_M$ remains constant providing the difference in the angles of rotation of the slides is constant:

$$\frac{R_N}{R_T} = \frac{K_N}{K_T} e^{\alpha_T - \alpha_N}. \tag{6}$$

The ratio of the maximum and minimum values of resistor $R_N$ is equivalent to 54 db and for resistor $R_T$ it is 21 db. The difference in the relation of these resistors to the angle of rotation of their slides is compensated by an appropriate gear ratio of their drives. The transmission is carried out by means of flexible dogs which clip on to the slides. The drive is designed to eliminate backlash. The same resistors are used as for other circuits of the inlversal bridge, for instance, for measuring capacity and the loss angle and for measuring resistance.

Figure 5 shows the experimentally obtained relation between the number of balancing operations n to an accuracy of 1% and the quality factor $Q_X$. Curve 1 was obtained with the use of the Ortonull, and curve 2 without it. For $Q_X \geq 2$ the two curves coincide and only four operations are required to balance the bridge (n = 4), two operations for each resistor. For smaller values of the Q factor n rises rapidly if the Ortonull is not used, whereas with it still only four operations are required to balance the bridge. At Q factors below 0.5 it is altogether impossible to balance the bridge without an Ortonull owing to the appearance of the "false zero" effect.

Figure 4 shows the conditions for the appearance of a false zero. The resistors $R_T$ and $R_N$ are wire wound and have a finite resolution. Let this resolution be such that impedance $Z_M$ varies when $R_T$ is changed in one step from the value characterized by point P" to a value characterized by point P' without passing through point P. The error due to a false zero will then be:

$$\delta = \frac{\Delta_T}{2Q_X^2}, \tag{7}$$

where $\Delta_T$ is the percentage resolution of resistor $R_T$.

Let $\Delta_T$ = 0.5%, then for $Q_X$ = 0.5 we shall obtain a $\delta$ = 1%, and for $Q_X$ = 0.1 we shall even get $\delta$ = 25%.

The error due to a false zero can be determined if the balancing near the zero point is made for several values of $R_N$. It is then possible to use a null indicator for obtaining a reading on the bridge. Such a technique however, is very lengthy.

The false zero effect exists even when an Ortonull is used, but it is considerably less pronounced. In order to find out what practical advantages one can expect from the use of an Ortonull many experimental balances of a Maxwell bridge were made. Figure 5 shows the relation between the accuracy of measurement $\delta$ and the quality factor $Q_X$. Curve 1 was obtained with an Ortonull whereas curves 2 and 3 without it. Curve 2 represents a complete balancing of the bridge, and curve 3 shows the case when the bridge is adjusted 20 times from a completely unbalanced position. The comparison of these curves shows that the use of an Ortonull makes it possible at low values of the Q factor not only to improve the balancing of the bridge but also to raise the accuracy of measurements.

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# AN AUTOMATIC DEVICE FOR MEASURING FUEL CONSUMPTION

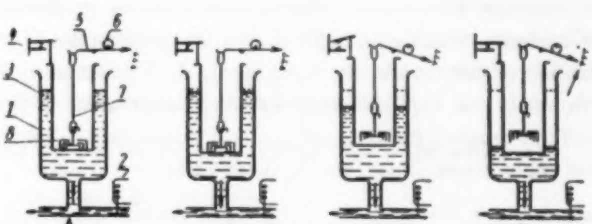
M. I. Brishkin

Translated from Izmeritel'naya Tekhnika, No. 6, p. 59, June, 1960

In the engine laboratory of the American Gulf Company automatic installations based on the hydrostatic method of measuring the weight of liquids are used for determining the fuel consumption of the engines under test [see Measurement Techniques, No. 8 (1958) and No. 1 (1960)].* The equipment periodically measures the time for which the engine at a definite condition of operations uses a given weight of fuel.

The schematic of the equipment (see figure, position A) shows the fuel container 1 stationary in its lower position and connected by a pipe to the main storage tank of the engine. A solenoid-operated valve 2 is placed between the tank and the container 1. When float 3 sinks owing to the flow of the fuel from container 1 to the engine, contact 4 is made and switches on the solenoid which opens the valve thus letting in the fuel for the periodic filling of container 1. The slow-releasing relay which connects contact 4 with valve 2 lets the level of the fuel rise a little higher than the spot at which the contact closes or opens.

When the signal for the measurement of the fuel is received, the control circuit is switched in such a manner that when contact 4 is closed, at a certain point in the downward movement of the float, it starts the timer but leaves the valve closed (position B in the figure). At the same time eccentric 6 turns, tips lever 5 which lifts by means of chain 7 weights 8 placed at the bottom of the float; the latter rises and breaks contact 4 (position C). Since the solenoid valve remains closed and the fuel continues to flow from the container to the engine, the level in the latter drops; the float sinks and again closes contact 4 (position D), and stops the timer. The amount of fuel



A B C D

consumed by the engine between the first and second closing of the contacts is determined by the value of the weights 8 (and the ratio of the container and float areas). Lever 5 may lift one, two, or three weights which are placed one on top of the other at the bottom of the float, according to the signal received from the control board, thus providing three different weighings of fuel equal to 45.4, 226.8, and 453.6 g. The error of measurement is 1% at the smallest weighing and 0.5% for the rest.

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*See English translations.

# MATERIAL RECEIVED BY THE EDITORIAL BOARD

## THE DEPARTMENTAL INSPECTION AGENCIES AND THE ASSIMILATION OF NEW MEASUREMENT TECHNIQUES

M. I. Dobrovinskaya

Translated from Izmeritel'naya Tekhnika, No. 6, pp. 60-61, June, 1960

With the present level of measurement technique assimilation in industry it is impossible to describe the work of test laboratories solely from the point of view of departmental inspection aimed at the maintenance of unified measures and instruments and their efficient utilization. Industrial test laboratories should play an important part in the development of technical progress in the sphere of measurements side by side with the scientific research institutes and design offices. Having studied the technology of a given production process, the industrial test laboratories should have a good knowledge of the technique of production measurements and the requirements of industry in this connection.

In his article entitled "Certain problems in the organization and activity of industrial test laboratories"* K. N. Katsman correctly notes that the basic task of the test laboratories in plants should consist in ensuring, by all the means at their disposal, correct results in technical measurements instead of maintaining unified measures or even supervising the condition of the measuring equipment. It follows from these tasks that industrial laboratories should tackle efficiently the application of existing instruments in production, and when necessary, develop new ones, having carefully studied the requirements of production. Production innovators should work side by side with engineers and technicians in furthering these tasks.

For a successful achievement of these aims, industrial laboratories should compile a working plan which should reflect production requirements in measures and instruments.

The activity of the laboratories in introducing new measurement techniques should be conducted in three ways:

1) assimilation of new instruments developed and manufactured by instrument-making plants;

2) assimilation of modernized measuring instruments existing in the laboratory;

3) development, production, and assimilation of new instruments taking into account the peculiarities of measuring apparatus in any given technological process.

The modernization and development of new measures and instruments is aimed at raising the accuracy of measurements and increasing labor productivity under mass production conditions.

One of the basic peculiarities in measuring electrical parameters of radio components consists of a large number of similar measurements. Moreover in these measurements the greater importance is ascribed to the percentage deviation from a given standard or the finding whether the product is a "reject" or a "pass" within certain tolerances, and the absolute value of measurements is less important. Instruments which provide a direct evaluation of the component parameters in a given form are therefore the most valuable for mass production.

Comparison methods are of great interest in raising the accuracy of measurements, and they consist in comparing the measured variable with standard measures. The result of this measurement often depends on the

*See "Measurement Techniques" No. 4, 1959.

error of the reference measure. In order to apply this method it is necessary to have capacity standards covering wide limits.

It should be noted that there is a considerable lack in capacity standards with wide limits of application, especially of large measures. Our plant, for instance, manufactures capacitors of 100 $\mu$f, yet the maximum value of capacitance boxes according to specifications equals 10 $\mu$f.

Our test laboratory developed, made, and introduced capacitance boxes up to 100 $\mu$f. For reference capacitances we use metal-foil hermetically-sealed precision capacitors type MPGT with a tolerance of $\pm 0.1\%$.

Our laboratory also developed, made and introduced in production, instruments which raised labor productivity and improved the quality of production:

1) a comparator resistance bridge which rejected components according to their degree of precision between 0 and $\pm 20\%$;

2) an instrument for scraping resistors to their nominal value;

3) semi-automatic equipment for sorting resistors into groups of $\pm 5$, $\pm 10$ and $\pm 20\%$ deviations;

4) a rack-mounted low-resistance ohmmeter with a range of 0 to 10 ohms;

5) a sorting device for dividing resistors into groups;

6) a comparator-bridge for sorting out capacitors according to their degree of accuracy, capacitance, and loss angle; the limits of the capacitance percentage scale were from 0 to $\pm 10\%$ with an error of $\pm 0.03\%$; the loss angle was measured in the range of 0 to 0.002 with an error of $\pm 0.0001$; the instrument had a visual indicator and measured with a balanced and unbalanced bridge; the latter method was used for mass production measurements;

7) a comparator-bridge for sorting out capacitors according to their degree of accuracy, capacitance, and loss angle; the capacitance percentage range was from 0 to $\pm 20\%$ with an error of $\pm 0.2\%$; the loss angle measuring range was from 0 to 0.018 with an error of 0.001; the instrument can measure with a balanced and unbalanced bridge, the latter method raises labor productivity in mass production;

8) an instrument for measuring the temperature coefficient of resistors.

In addition several instruments were modernized.

Owing to the introduction of new and modernized instruments we were able to raise productivity and improve labor conditions as well as increase the accuracy of measurements.

# INFORMATION

## THE 1961 INTERNATIONAL SCIENTIFIC AND TECHNICAL CONFERENCE ON MEASUREMENT TECHNIQUES AND INSTRUMENT MAKING (IMEKO).

V. O. Arutyunov and A. N. Gavrilov

The All-Union Scientific Glass Research Institute
Translated from Izmeritel'naya Tekhnika

The first International Scientific and Technical Conference on Measurement Techniques and Instrument Making (IMEKO), organized by the Hungarian Scientific and Technical Society for Measurement Techniques and Automation (MATE), the Polish Scientific and Technical Society (NOT), and Scientific and Technical Society of the Instrument Making Industry of the USSR, was held in Budapest in November 1958.

The object of the Conference consisted in discussing the latest achievements in the sphere of measurement techniques and instrument making and in exchanging scientific and technical information. The Conference was attended by representatives from 18 countries. The Soviet delegates read 16 papers of the 150 presented to the Conference. The proceedings of the Conference have been issued in five volumes (Acta IMEKO); the papers are given in their original language and in an abridged translation in the working languages of the Conference.

The Presidium of the 1958 IMEKO Conference decided to hold such conferences once every 2-3 years. It was decided to hold the next IMEKO Conference in 1961.

By the end of 1959 representatives of Scientific and Technical Organizations of more than 15 countries agreed to take part in the International Preparatory Committee (IPC). At the meetings of the IPC, which were held in Budapest from February 10 to 14, 1960, organizational, scientific, and technical questions were discussed in connection with the preparation of the IMEKO Conference in 1961. The following organizational principles were developed and approved by the IPC. "A scientific and technical organization or association of a country can become a member of the International Preparatory Committee, providing it undertakes to assist in the organization of the Conference. Experts of countries where no suitable scientific and technical organizations exist can take part in the work of the Preparatory Committee in a consultative capacity. Every member of the IPC must provide papers on the subject matter of the Conference and actively help in the preparation and the holding of the IMEKO Conference in 1961." The IPC has established a secretariat for operation between the sessions headed by an executive secretary who forms part of the IPC with a deciding vote.

On the basis of the operational principles and by virtue of the powers delegated to the representatives, the following IPC was approved: it consists of representatives of scientific and technical organizations and associations of Great Britain, Belgium, Bulgaria, Hungary, GDR, Denmark, Italy, Korean People's Republic, Poland, Rumania, USSR, Czechoslovakia, and Sweden; D. Shtriker (Hungary) was appointed as executive secretary of the IMEKO; representatives of Austria, Albania, India, USA, France, FGR and Yugoslavia are taking part in the IPC in a consultative capacity.

The IPC accepted the proposal made by the Hungarian society MATE to hold a 5 day Conference in Budapest sometime between June 15 and July 15, 1961.

After careful consideration the IPC approved the following standing orders for the work of the IMEKO Conference in 1961. At the plenary sessions the most important papers of a general character will be read, those

dealing with important problems in the sphere of measurement techniques and instrument making, as well as summing-up reports. The section on technology and organization of production will be read papers of interest, respectively, on the computation and design of instruments and electronic instruments of a general nature; as well as reports on problems not directly related to instruments and measuring equipment (general principles of design and computation, construction, technology and production organization of instruments, and the computation of common electronic elements).

Moreover, in conjunction with the IFAK Technical Committee, the work of a section on "Problems related to measurement techniques and automation" is being organized.

The remaining seven sections will deal with problems and methods of measuring: geometrical and mechanical quantities, time and frequency, thermotechnical quantities, ionizing radiations, with instruments and methods in physicochemical measurements (photometry, spectroscopy, colorimetry, electrochemistry, gas analysis, etc.) and with electromagnetic and radiotechnical measurements.

The working languages of the conference will be English, German, Russian and French.

The International Preparatory Committee approved the requirements to which the papers submitted must conform. They must contain original results of scientific or practical value, a brief description of the state of the development of the subject in question and recommendations for its further development.

Reviews may be presented subject to the approval of the secretariat; they must contain a description of scientific and practical applications of the achievements in the sphere under consideration and suggest further means of development in this sphere.

The papers must be submitted in not fewer than two working languages of the conference (two copies in each language). Illustrations must also be submitted in the two copies.

Papers must be submitted only through the member organizations of the International Preparatory Committee. The papers of Soviet scientists and engineers should be submitted to the regional or republican administrations of the Scientific and Technical Society (NTO) of the Instrument Making Industry, which will forward them, after approval by the Presidium of the NTO, to the IMEKO secretariat before November 1, 1960.

For the purpose of organizing our participation in the 1961 IMEKO Conference, the Presidium of the NTO formed a Soviet IMEKO committee which has been entrusted with all the organizational and technical work in selecting the papers submitted.

## INTERNATIONAL CONFERENCE OF THE ISO AND THE IEC ON ACOUSTICS AND ELECTROACOUSTICS

I. G. Rusakov

A conference of the International Standardization Organization, Technical Committee, ISO/TC-43 (acoustics) and the International Electrotechnical Commission, Technical Committee, IEC/TC-29, (electroacoustics) was held in Italy (Rapallo) on March 29 to April 9, 1960.

Architectural acoustics. Prof. Costen (Netherlands) read a paper on the test results obtained from the use of sound-absorbing material "Silan" (slabs made of mineral wool) in 16 reverberation chambers of different countries including the USSR. These tests were carried out in order to establish the effect on sound-absorption of various factors: the diffusion field in the chambers, the area of the sample, the volume of the chamber, the peculiarity in the position of the sample, and the presence and characteristics of the diffused sound.

The author came to the conclusion that in order to obtain uniform results it is necessary to make the volume of reverberation chambers not less than 200 $m^3$ and the area of the sample 10-12 $m^2$. It is also necessary to ensure good diffusion of the sound field by means of sound dispersion and it is also necessary to standardize the border conditions for the samples.

As the result of the ensuing discussion a new draft of ISO recommendations on the measurement of sound-abosorption in reverberation chambers was compiled.

Audiometric threshold of audibility. The Soviet Union took an active part in the experimental work organized by the secretariat of the working group in preparing recommendations on the audiometric threshold. In 1958-1959 the D. I. Mendeleev All-Union Scientific Research Institute of Metrology (VNIIM) compared reference Soviet telephones with French and American telephones. Objective comparisons were made by means of a reference artificial ear IU-3 and subjective ones by a specially trained crew. Thus, the VNIIM provided the required link in the chain of mutual comparisons of telephones in five countries (USA, USSR, Britain, FGR, France). Moreover the USSR had previously conducted exhaustive determinations of the threshold of audibility on the telephone (in the Institute of Biophysics of the Acad. Sci. USSR). All this data formed an organic part in the series of determinations of the international threshold and were fully approved by the working group of the conference. The preliminary values of the international threshold were agreed to at the conference, the final values will be prepared taking into consideration all the remarks and additional data. The recommendations are ready for approval by the national committees.

Thus, the formulation of an international recommendation for a unified base in audiometry has been completed and the possibility of a unified system for choosing ear prostheses established. The conference also discussed briefly and adopted a decision on preparing a recommendation on the threshold for bone-conducting telephones.

Determination of the intensity of noise. On the question of determining the intensity of noise on the basis of spectral analysis data a discussion developed concerning the draft recommendation proposed by Prof. Stevens (USA). The German delegation (Dr. Zwinker) proposed replacing the octave and one-third octave filters by special noise measuring filters whose bandwidth is matched to critical pitch differentiation bands. In the last German version the critical bands were taken as combinations of one-third octave bands. Another peculiarity of the German proposals consisted of an original graphic method of accounting for the mutual masking of noise components. Prof. Stevens' proposals were criticized from the point of view of the advisibility of using loudness as a practical measure of noise. Papers have recently appeared in which it is asserted that a direct evaluation of noise differs from its loudness evaluation.

The conference decided to approve the evaluation of loudness proposed by Prof. Stevens. At the same time a more accurate procedure for evaluating the loudness of noise on the basis of the German draft will be developed and submitted at a later date.

Evaluation and normalization of noise. A draft proposal for the evaluation and normalization of industrial and commercial noises from the point of view of protecting hearing and the requirements of oral communications was submitted to the conference. It was based on Dutch proposals (Prof. Costen) to use standard curves which determine the degree of noise by means of spectral components in octave bands which can be placed below these curves.

The ISO draft is similar to the standards developed in the USSR for the spectral noise tolerances in living premises, and therefore, the Soviet delegation supported the draft. According to the draft the maximum tolerable noise during five hours of a working day should not exceed curve 85, i.e., a curve which passes through the octave level of sound pressure 85 db at frequencies of 500, 1000, and 2000 cps. Noise tolerances from the point of view of direct and telephone conversations were also established.

The conference also prepared a new draft of proposals for the method of measuring autotransport noise.

Preferred frequencies for acoustic measurements. A document was submitted in order to be adopted as an ISO recommendation which established a number of reference frequencies for measurements and for selection as central frequencies of octave, semioctave, and one-third octave filters. This series is based on the frequency of 1 kc. The frequencies of 16, 31.5, 63, 125, 250, 500, 1000, 2000, 4000, 8000, and 16,000 cps were chosen as

refence frequences. The half octave and one-third octave frequencies are distributed uniformly between these frequencies with a small degree of approxmiation. The acceptance of standard recommended frequencies will eliminate the multiplicity of such frequencies, which is particularly nefarious when noise data obtained in various countries with different frequency filters is being compared.

The IEC/TC-29 conference also discussed a number of interesting and important questions of which we shall mention the following.

Noise meters. A draft specification for commercial noise meters was dispatched for consideration six months ahead according to rule. The USSR voted for the draft. Among other countries only the USA voted against it. As the result of discussion certain (mainly editorial) corrections were adopted and the draft accepted as an IEC publication.

The alterations amounted to the following: the name of the instrument was specified as "noise meter" (without mentioning "commercial"), the possibility of using the instrument both in a free and diffused noise field is mentioned; the tolerance characteristics are specified more precisely. A new draft specification for a more accurate noise meter was also discussed. This specification will be compiled similarly to the one already adopted, with alterations leading to an increased accuracy and decreased tolerances in its frequency characteristics. The draft will be dispatched to the national committees of the IEC as a secretarial document for their consideration. The next task consists in preparing specifications for filters and noise analysers, and instruments for measuring short and nonstationary noises.

Transducers for measuring vibrations and shocks. The conference discussed a list of characteristics of vibration and shock transducers, and agreed on certain terms and quantities used in their specification. The values of their characteristics or tolerances have not yet been discussed.

A document dealing with the characteristics of a vibration (or shock) machine for testing electronic and other equipment with respect to shocks has been preliminarily discussed. It was decided to include in the next working program the problems of calibrating vibration and shock transducers, balancing the rotors of machines and measuring mechanical impedances of machine bases. The work of the section on vibrations and shocks attracted the attention of delegations from 11 countries.

## CORRESPONDENCE COURSES ON THE APPLICATION OF SEMICONDUCTORS IN INSTRUMENTS

The Central Administration's Social Institute of the Scientific and Technical Society of the Instrument-Making Industry is organizing correspondence courses for the purpose of improving the knowledge of engineers and technicians in the sphere of the application of semiconductors in instruments.

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The curriculum of the correspondence course covers one year and consists of nine lectures comprising 35-40 author's pages.

The material will be dispatched to the subscribers as from the 3rd quarter of 1960. The material will not be sold to the public.

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Requests should be addressed to:

Correspondence courses of the Scientific and Technical Society of the Instrument-Making Industry, Volkhonka 5, Moscow, G-19. Telephone B 3-32-46.

# COMMITTEE OF STANDARDS, MEASURES, AND MEASURING INSTRUMENTS

## CHANGES IN THE CURRENT INSTRUCTIONS FOR CHECKING MEASURES AND MEASURING INSTRUMENTS

N. M. Staroverov

Translated from Izmeritel'naya Tekhnika, No. 6, p. 64, June, 1960

In its instructions 20-56, 33-56,and 4-53 the Committee of Standards, Measures and Measuring Instruments has introduced several changes and additions which take into account the coming into force of new standards on instruments and the experience gained in checking over the last few years.

In the instruction 20-56 for checking water meters and their testing equipment,Table 2 is now issued in the following form:

TABLE 2

Standard Flows for Water Meters with Vertical Vane Wheels

| Water meter size, mm | Nominal flow, $m^3/hr$ | Standard flows, $m^3/hr$ tests | | |
|---|---|---|---|---|
| | | 1st | 2nd | 3rd |
| 15 | 1 | 1.5 | 0.3 | 0.15 |
| 20 | 1.6 | 2.5 | 0.5 | 0.25 |
| 25 | 2.5 | 3.5 | 0.7 | 0.35 |
| 30 | 4 | 5.0 | 1.0 | 0.5 |
| 40 | 6.3 | 10.0 | 2.0 | 1.0 |
| Tolerances in water meter readings, % | | ±2 | ±2 | ±3 |

The second column of Table 3 is deleted and point 37 formulated anew:

"In order to determine the error in the reading of water meters they are placed on the test table either singly or in groups. In the latter case they must have the same nominal flow and be connected in such a manner that the water flows through all the instruments connected in series into the measuring tank."

The table of supplement 1, point 3 is enlarged by a sixth column which reads:

| Variations in the water level in mm, which correspond to the variations of volume in 1 $in^3$, not less than |
|---|
| 6 |
| 3 |
| 1.5 |
| 0.3 |
| 0.15 |

In supplement 2, point 14, in the table "Technical characteristics of water meters VK, VKM, VMKh and VV" the second line (horizontally) now reads as follows:

| | | |
|---|---|---|
| Nominal flow, $m^3$/hr | 1; 1.6; 2.5; 4; 6.3 | Shown in Table 3 |

Instruction 33-56 for checking milk measures is enlarged by a supplement which describes the technique of checking milk measures by the weighing method with the help of table scales (with a platform) of the capacity of 10 to 20 kg and an error at maximum loads of 5 and 10 g respectively.

The capacity of the milk measure is determined by the weighing method on one arm of the balance, the scale of the milk measure must be checked at least in three places and at the full capacity. The weighing results are determined with an accuracy of up to 10 g.

In checking by the weighing method the mass and temperature of the water poured into the milk measure is determined. The mass of the water is determined as the difference between the weighing of the milk measure before and after it is filled with water.

The water temperature (in checking, the temperature is kept at $20 \pm 10°C$) is measured immediately before the weighing with a thermometer having 0.5°C graduations.

The correction for a temperature of 20°C is calculated by multiplying the mass of water by the correction coefficient obtained from the following table:

| Temperature interval, °C | Correction coefficient |
|---|---|
| 5-18 | +0.002 |
| 19-28 | +0.003 |
| 24-28 | +0.004 |
| 29-31 | +0.005 |

Considerable alterations have been made in the sections dealing with technical requirements, means and methods of checking of instruction 4-53 on checking commercial spring manometers, vacuum gauges and vacuum manometers. The main alterations refer to the requirements in marking the instruments, dials and scales, as well as a more precise definition of the reference instruments used in checking and the classification of instruments according to GOST 8625-57. Instruction 4-53 with the above alterations has been issued by the State Standards Press.

# SIGNIFICANCE OF ABBREVIATIONS MOST FREQUENTLY ENCOUNTERED IN SOVIET TECHNICAL PERIODICALS

| | |
|---|---|
| AN SSSR | *Academy of Sciences, USSR* |
| FIAN | *Physics Institute, Academy of Sciences USSR* |
| GITI | *State Scientific and Technical Press* |
| GITTL | *State Press for Technical and Theoretical Literature* |
| GOI | *State Optical Institute* |
| GONTI | *State United Scientific and Technical Press* |
| Gosénergoizdat | *State Power Press* |
| Gosfizkhimizdat | *State Physical Chemistry Press* |
| Goskhimizdat | *State Chemistry Press* |
| GOST | *All-Union State Standard* |
| Gostekhizdat | *State Technical Press* |
| GTTI | *State Technical and Theoretical Press* |
| IAT | *Institute of Automation and Remote Control* |
| IF KhI | *Institute of Physical Chemistry Research* |
| IFP | *Institute of Physical Problems* |
| IL | *Foreign Literature Press* |
| IPF | *Institute of Applied Physics* |
| IPM | *Institute of Applied Mathematics* |
| IREA | *Institute of Chemical Reagents* |
| ISN (Izd. Sov. Nauk) | *Soviet Science Press* |
| IYap | *Institute of Nuclear Studies* |
| Izd | *Press (publishing house)* |
| LÉTI | *Leningrad Electrotechnical Institute* |
| LFTI | *Leningrad Institute of Physics and Technology* |
| LIM | *Leningrad Institute of Metals* |
| LITMiO | *Leningrad Institute of Precision Instruments and Optics* |
| Mashgiz | *State Scientific-Technical Press for Machine Construction Literature* |
| MGU | *Moscow State University* |
| Metallurgizdat | *Metallurgy Press* |
| MOPI | *Moscow Regional Pedagogical Institute* |
| NIAFIZ | *Scientific Research Association for Physics* |
| NIFI | *Scientific Research Institute of Physics* |
| NIIMM | *Scientific Research Institute of Mathematics and Mechanics* |
| NIKFI | *Scientific Institute of Motion Picture Photography* |
| NKTM | *People's Commissariat of the Heavy Machinery Industry* |
| Obrongiz | *State Press of the Defense Industry* |
| OIYaI | *Joint Institute of Nuclear Studies* |
| ONTI | *United Scientific and Technical Press* |
| OTI | *Division of Technical Information* |
| OTN | *Division of Technical Science* |
| RIAN | *Radium Institute, Academy of Sciences of the USSR* |
| SPB | *All-Union Special Planning Office* |
| Stroiizdat | *Construction Press* |
| URALFTI | *Ural Institute of Physics and Technology* |
| TsNIITMASh | *Central Scientific Research Institute of Technology and Machinery* |
| VNIIM | *All-Union Scientific Research Institute of Metrology* |

NOTE: Abbreviations not on this list and not explained in the translation have been transliterated, no further information about their significance being available to us — *Publisher.*

Publication of a "Soviet Instrumentation and Control Translation Series" by the Instrument Society of America has been made possible by a grant in aid from the National Science Foundation, with additional assistance from the National Bureau of Standards for the journal *Measurement Techniques.*

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